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BACTERIOLOGICAL EXAMINATION OF CANNED FOODS

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1. Some Safety Measures in Canning Factories. 16 pages.
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3. Tomato Pulp. 14 pages.
4. Preliminary Bulletin on Canning. 65 pages.
5. The Examination of Evaporated Milk. 24 pages.
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13. Washing and Cleaning Cans. 18 pages.
14. Bacteriological Examination of Canned Foods.

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A BRIEF OUTLINE UPON THE BACTERIOLOGICAL EXAMINATION OF CANNED FOOD

Introduction

The canning of food is a process which depends for its success upon sterilization of the product and its container and the subsequent exclusion of infection. Until the last two decades, the art was developed by systematic experimentation without the aid of the sciences, the industry having been built upon experience and empirical formulas. It was not until 1895, when Professor H. L. Russell of the Wisconsin Experiment Station made the first study in this country upon the cause of spoilage in canned peas, that the real reason for a certain process was established. The following year, 1896, Professor S. C. Prescott and Mr. W. L. Underwood, at the Massachusetts Institute of Technology, began a study of the cause of the souring of corn and presented the result of their work to the Boston Society of Arts in October of that year. Later they worked upon sour peas. They presented their first paper before the Atlantic States Packers' Association in 1898, a second in 1899, and a third in 1901. The first paper was received with skepticism, but the subsequent establishment of facts was so convincing that all doubts concerning the value of scientific investigation were removed. To these two men must be given the major credit of introducing bacteriology into the canning industry.

Mr. E. W. Duckwall published his "Bacteriology of Canned Foods" in 1899, and "Canning and Preserving with Bacteriological Technique" in 1905. He has been the largest contributor of popular and technical articles upon canning in the trade journals.

In 1903, Mr. H. A. Harding and Mr. J. F. Nicholson, of the New York Experiment Station (Geneva), made reports of their studies upon swelled peas.

Dr. C. N. McBryde of the Bureau of Animal Industry reported upon "A Study of the Methods of Canning Meats" in 1907.

Mr. J. P. Zavalla, at the University of California, described a number of organisms from swelled cans in "Canning Fruits and Vegetables," in 1916.

Numerous articles have appeared in journals and reports which have a bearing upon bacteriological studies, but no attempt has been made to summarize or to make this information available. It must therefore appear obvious that bacteriology as a science has not risen to its opportunities in the development of this very important industry.

The best directions to follow upon bacteriological technique are to be found in "Diseases of Plants," by Dr. Erwin F. Smith, published by the Carnegie Institution, Washington, 1905–1914. This treatise was prepared without any reference to the examination of foods, but the details upon technique are given with so much clearness and detail that they can be readily adapted.

Object of the Examination

The bacteriological examination of canned foods usually has for its object one of three things; first, to determine whether foods which appear normal are sterile; second, to determine whether foods which appear to be defective are sterile, and if not sterile, whether the spoilage be due to under-processing or to leaks; third, to determine from the finished product the character of the original material—in legal verbiage whether the product is composed in whole or in part of filthy, putrid, or decomposed material. Work along the first line is conducted upon foods as they are being packed so as to be able to anticipate spoilage or to make changes in processing which may be advantageous. Examination of the second class is made after the product gives evidence of being imperfect. The examination may be made at any time after packing and must differentiate between distention of the sterile can through physical expansion and by gas developed through chemical action from swelling due to micro-organisms, and furthermore determine, if possible, in infected foods, whether the cause be insufficient sterilization or due to a leak. The third line of examination is conducted principally upon tomato products as purée, pulp, soup stock, etc., to determine whether they will comply with certain promulgated standards for purity. To attain these objects requires different modes of procedure which will be taken up in detail under appropriate sections.

The examination of canned foods should be conducted in such a systematic manner as to develop all the facts necessary to arrive at a proper conclusion as to their true condition and the cause of any defects. First of all, there should be a clear history of the foods in question, the character and the quality of the material used, the method and time required in preparation, the temperature and time used in fore-cooking, exhausting, processing, the degree of cooling, the conditions of storage, the length of time packed, and the approximate percentage of spoilage if any should exist. This historical part is not essential to a laboratory examination, but it may aid the analyst and in some cases save time and a great deal of unnecessary work. The relation existing between the packer and the analyst ought to be such that there should be no hesitancy in furnishing the data covering these and any other points which might aid in getting a prompt solution in a matter of difficulty or in avoiding future trouble. A history which develops long delayed husking of corn or threshing of peas, insufficient agitation in the continuous cooking of tomatoes, or the stacking of foods while hot in solid blocks in the warehouse, or other obvious point of mismanagement, reduces the range and the number of examinations which need to be made. The majority of packers, especially with the first samples sent to a laboratory for examination, attach either no history, or an exceedingly brief one, and expect an immediate analysis with a statement of the condition present, and if there be trouble, how it can be overcome or avoided in the future. It is only the simplest and glaringly apparent cases which will admit of a prompt answer, and in the absence of a history it may require two weeks to be reasonably certain concerning sterility.

An analyst who undertakes to make a bacteriological examination of canned foods should have a fair knowledge of the processes employed and of the factory operations in order to interpret his findings in relation to their causes. The mere finding of an organism in a can is of little practical value unless one can be reasonably certain how it came to be there and how a recurrence may be avoided. It may happen, therefore, in many examinations that the actual microscopic or cultural work will be of secondary importance, and in fact a very great deal of the information will be elicited without resorting to the finer laboratory methods.

Explanation of Terms Used

There are terms used in the food preserving industry which need a brief explanation in order to make the meaning clear in the following discussion.

The term "can" has acquired a double meaning by usage, the first applying to the container for foods or other materials and the second to the container and its food content. The grocer sells a can of peas, a can of corn, or a can of salmon, and the container and contents are always delivered together. The English use the term "tin" in the same sense.

A normal can is one in which the product is sterile, the container furnishing a hermetic closure with the ends flat or slightly concave.

A stuffed or overfilled can is one in which the contents exceed in volume the space within normally collapsed ends, the sealing having been accomplished by exerting pressure.

A slack filled can is one that is not as well filled as it should be in the proper preparation of the food.

A collapsed can is one in which the sides are drawn in to a greater or less degree due to a high vacuum. Extreme collapse may be seen in cans which are not quite full and which have been placed on their sides while cooling. A spray of cold water striking the upper side of the can causes condensation of the steam with a resulting vacuum. The action may be so violent as to cause the cans to bend out of shape.

A plain can is one having no protective coating upon the tin.

A lacquer-lined can, in the trade called enamel lined, is one coated with lacquer on the inside in order to limit the action of the food upon the metal. Its chief use is to preserve color in such products as berries, cherries, beets, etc.

An open top can is one in which one entire end is open until the can is filled and sealed, the end constituting the cover.

A solder top can is one with an opening in the top through which the can is filled and which is subsequently closed by means of a cap and sealed with solder.

A vent filling can is one which is filled through the vent hole in the cover. Its use is limited to liquids like milk.

A key opening can is one in which the metal is partly cut by a machine before the can is formed and which is opened by being torn along the line of the partial cut by means of a key. The same result is also obtained by making the separation along a line of solder at one end.

A wax top can is one which is sealed by means of wax instead of solder. These are used in home canning only.

A hemmed cap is one which has the solder for closing applied to its circumference.

Head space is the space between the cover and the food.

Canner's end or packer's end is the term used to designate the end of the open top can applied by the packer.

Factory end is the designation of the end attached by the can maker. The factory end usually has some special code marks in the panels to designate the factory in which the cans were made, and when they were made. Some packers also make code imprints to record their goods.

A lap seam is one in which one end of the body piece overlaps the other and with solder flowed between to make the union.

A lock seam is one in which each end of the body is formed into a close-fitting hook; the hooks engage each other and are united by means of solder on the outside.

There are four manufacturing operations which affect the product and which influence to an extent the sterilization. They are blanching or fore-cooking, exhausting, processing, and cooling.

Blanching consists in a fore-cooking of a product, first for the purpose of removing the more or less gummy substance upon the surface of such vegetables as peas and beans; second, for the purpose of making a product more or less flexible so that it may be packed without breaking, as asparagus; third, to permit the packing of a greater quantity in a can, as spinach; fourth, to force water into a product and cause it to become tender, as in beans; fifth, to secure a more uniform color, as in fruits; and sixth, for its cleaning effect. It is not a bleaching process as many infer from the term. The time used in blanching varies from one to fifty minutes, usually between two and five minutes. The operation has little influence upon the final sterilization.

Exhausting is the process of removing a part of the air just prior to sealing. It is accomplished by heating, or mechanically by producing a vacuum. It is not an essential operation for sterilization, though advisable for commercial reasons.

The process or bath is the operation of heating the cans after the final sealing. It is the essential operation in sterilization and is carried out below, at, or above the boiling point, depending upon the product and the kind of organisms present. In almost all commercial packing the work is completed in one heating.

Cooling is the lowering of the temperature as quickly as possible after the process is completed. The primary effect is to make a better appearing product, but secondly it appears to be a factor in insuring the sterility of some products.

Cold pack was a term which originally referred to foods packed at home and preserved with a chemical preservative, as salicylic acid or sulphurous acid. The term gradually died out as preservatives were prohibited, but it has been resurrected recently and applied to home canning in which the product is placed in the cans cold and then heated, which is in reality an adaptation of regular commercial methods to home conditions.

General Examination

The number of cans required for an examination to determine the presence or character of spoilage in a pack will vary considerably. In no case should dependence be placed on the examination of a single can. A half-dozen cans should be the minimum, and in a doubtful case a dozen or a case should be available. Furthermore, the selection of the cans should be thoroughly representative of the different parts of the pack, the outside, top, bottom, and inside of the stack, and from the runs on different dates or upon dates when unusual conditions may have been present. The taking of samples from the inside of a stack, if the cans have been piled closely together, is of particular importance as those upon the outside may be in perfect condition while those within may be undergoing spoilage of a type known as "flat sours."

The first step in the examination of cans is to observe the gross appearance. The cans are divided into two classes, the solder cans and the open top or double seamed cans. In the former the ends and the cap hole are closed by soldering, while in the latter the can is made by crimping or double seaming the bottom to the body piece and making the closure of the filled can by a similar operation in attaching the top. No solder is used except upon the side seam; a cement substance, rubber composition, or a paper gasket being used to make a hermetic joint with both bottom and top to the body.

The cans should be bright, clean, and free from rust. If the can be lacquered, the coating should be applied to the entire surface to protect against rust, and not to the ends alone. End lacquering or painting is quite often applied to cover rust. The presence of rust may be indicative of exposure to weather, to damp storage, or to attack from juice escaping from adjoining leaky cans. The significance of the presence of rust has a special bearing upon the question of pin hole perforations, whether originating from without or within the can, and upon the general lack of care in storage or transit. The losses from rust perforation from without the cans sometimes develop into considerable proportions due to the juices escaping from one can contaminating a number of others and these in turn becoming leakers and extending the trouble.

The contour of the cans should be normal, that is, with straight sides and concave ends. Flat cans such as used for meats and asparagus and large round cans may be more or less flattened due to the strong vacuum present, but deep dents or batter marks are indicative of rough handling. An injury may not be limited to the dent in the body, but may result in small fissures through solder joints or breaks in the double seam.

A flat or a concave end is indicative of a vacuum and is highly desirable as a guide to the consumer as to the sterility of the product. A concave end is not a sure guarantee that the can may not be a flat sour, and a convex end may indicate an overfilled can or a springer as well as a swell. The proportion of cans which are imperfect when the ends are normal is relatively so small that any deviation from this condition is regarded as unmerchantable. The packer who does not employ the necessary measures to secure a proper vacuum is at least negligent in not insuring against a trade hazard.

The simplest test which may be made for sterility is to place the can or cans very shortly after packing in a constant temperature oven at 37° C. and leaving them there from one to fifteen days. With most products the warm temperature will accelerate the development of the bacteria which cause swells and flat sours, and produce the gross effect of distorting the ends of the cans in the one case or producing a sour taste in the other. Incubation at 37° C. is sufficient for practically all fruits and most vegetables, but it is preferable in the case of the latter and with meats, fish, and milk to also provide for incubating at a higher temperature, about 50 to 55° C. There are thermophilic forms present on these products which may not develop at the lower temperature, or which develop so slowly as to escape detection. The thermophilic forms are nearly all soil types and very slow of growth, produce little or no gas, but produce acidity. They occur particularly in corn, peas, pumpkin, squash, sweet potatoes, etc., which have been closely stacked in the warehouse without having been cooled. A short incubation of from 24 to 48 hours is not adequate, and incubation at the lower temperature alone is not sufficient to determine sterility.

The effect of incubation is to stimulate the growth of the micro-organisms and those which are gas producing will cause swelling of the cans. Gas production may begin as early as the first day, though it may be delayed several days or even weeks. Swells produced soon after packing are usually harder and more frequently cause the cans to break than those which develop later. Sudden swelling, but to a very moderate degree and with a tendency to remain stationary, is most often indicative of an overfilled can, as the swelling is due to an expansion of the contents or of the enclosed gases. Usually such cans will collapse when placed in cold water or in a refrigerator, while a true swell will only partially subside under such conditions. Strongly acid products may set up action within the can, generate more or less hydrogen, and have the appearance of a swell. The condition develops much more slowly than a swell.

In case the organisms are not gas producing, it is not so easy to recognize any change from an external examination of the cans. Corn packed in the Maine style may be so liquified that it is clearly recognizable on shaking, as may also meat, fish, pumpkin, and squash, while milk may gelatinize. Any further examination of the can must be conducted after it has been opened.

The ordinary laboratory incubator is not of adequate size to accommodate many cans at a time and if examinations are to be made systematically during a season, more rugged and roomy apparatus is necessary. Chicken incubators are very much less expensive than laboratory incubators, and will hold a temperature sufficiently constant for all practical purposes. The writer has used refrigerators with inside heaters and has found them very satisfactory. The household sizes will easily hold from 100 to 500 cans. A closed water tank is placed inside and connected with a heating coil on the outside, and a thermo-regulator may be used to control the temperature. Electric heaters are also available in place of gas and oil. Many canners have insulated rooms built in their plants, and select a number of samples from the pack of each day, and so need considerable space. These rooms usually hold a hundred cases or more, and are generally heated by steam or hot water pipes.

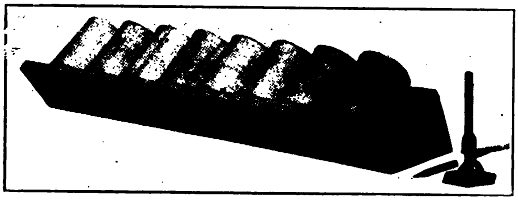
If the can preserves its normal shape after incubation and has cooled to room temperature, a puncture is made in the end with a vacuum gage to determine whether a vacuum is or is not present. A can showing only three or four inches of vacuum has a low vacuum; from six to nine inches a moderate vacuum, and ten to fifteen inches a very good vacuum. If the can presents the appearance of a springer or a swell, a flame is directed over it and a small puncture made to determine whether the gas given off will burn. The gas generated by the chemical action of the contents upon the container is hydrogen and inflammable, while that produced by the growing organisms is carbon dioxide for the major portion and noninflammable. The cover is removed by cutting on the side very close to the top so as to cause the minimum disturbance of the contents. An inspection is made as to the condition of the contents, whether normal in appearance as to color, texture, and consistency, whether there be any foreign odor, or any unusual flavor. In the case of sweet potatoes, meats, fish, or other equally dry products, an examination is made for small spots which might be infected, as owing to the absence of liquid the growth remains circumscribed. The fill of the can is noted, whether there be head space or whether the contents extend above the normal level of the cover, and in the latter case the weight should be taken. The condition of the can, whether it be bright, have a galvanized

Removing the cover with the least disturbance of the contents.

appearance, have rust spots, black patches, or be eroded, is also important as indicating normal action upon the container or acceleration by heat or admission of air. Thus far the examination has proceeded without the use of the microscope, and if it has been carefully done, it will have elicited much of the information desired.

Microscopical Examination

The microscopic examination of the liquid from a can which has been incubated from twenty-four to forty-eight hours will generally give the earliest indication of pending trouble. The majority of cases of spoilage are caused by motile forms which are very active at the incubating temperature, but which may be quiescent or very slowly motile at room temperature. This test may give a positive result well in advance of any swelling or physical evidence of spoilage. It is so simple that it can be used by a keen observer with limited instruction in the use of the microscope and without special training in bacteriology; some packers have obtained the necessary equipment and make their own examinations. This is the test most to be relied upon to determine whether reprocessing is necessary.

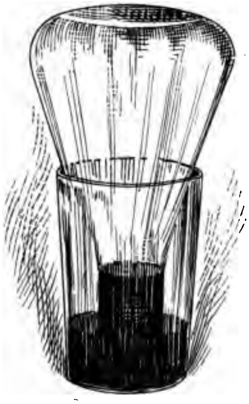


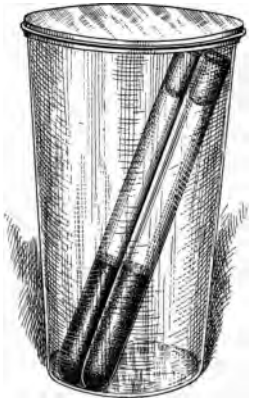
The best position for making a sterile puncture in obtaining a sample, making an inoculation or relieving a springer.

Instead of cutting off the top of the can, some workers prefer to make a puncture and to take the sample for the microscopic mount by means of a capillary pipette or wire loop. The puncture is used through which to take samples for culture when test tubes are used in the incubator instead of the cans. A puncture is also made in inoculating other cans from a diseased can or from pure cultures. The making of the puncture may seem to be such a simple operation that a description of a method is not warranted, but there are some methods that are simpler and better than others. The preferred method is to first wash the can, then place it in an inclined position at from 30 to 45°. The end of the can and upper part of the side is then subjected to the action of a Bunsen flame or one of similar type. The steel awl used in puncturing is also heated in the flame. The most suitable site is a point on the upper side near the end, as the contents will settle away from contact with the wall and will not interfere either with drawing the sample or later in making a closure with solder. The puncture should be made while the flame is being directed upon the spot. All normal cans have some vacuum so that the air tends to rush in the moment the puncture is made and to carry such infection as may be present. A flame will heat such gas as may be present inside the can and thus lessen the vacuum and will sterilize the indrawn air. The washing of the cans with antiseptics, etc., is used but has no advantage over the flame, has some disadvantages, and is not so convenient. If a number of cans are to be examined, they may be held at the proper angle in a trough. The tipping of the puncture is easily accomplished as no contents reach the spot. The puncture method has its special use where the contents contain a considerable quantity of liquid as any part of the liquid will serve for examination, since any organisms which may be present will be well distributed, and also when it is desired to make inoculations. It may also be employed where large numbers of cans are to be examined, as the contents are not lost and need not be transferred to new ones. It has the disadvantage of not permitting inspection, nor of being able to get at the center of cans where the contents are more or less solid as with meats, fish, etc.

The direct examination of the material should be supplemented by inoculation of culture media in all cases of doubt. The media selected should correspond with that of the product under observation. If tomatoes are being studied, tomato bouillon, tomato gelatin, and tomato agar should be used. The organisms present upon peas will not do well upon media containing tomato and vice versa, and the standard laboratory media frequently fail because the reaction does not correspond closely enough to that of the product upon which the organism is found or it is lacking in some essential for growth. It is also necessary to afford both aerobic and anaerobic conditions, as it frequently happens that growth will take place under one condition and not under the other. In canned foods anaerobic forms are particularly prone to occur and, if this detail be omitted, no organisms develop. It is furthermore advisable to hold the cultures at room temperature, at 37° C., and in the case of corn, peas, hominy, baked beans, sweet potatoes, meats, and fish, at 55° C.

Convenient forms of apparatus for growing organisms in vacuum are illustrated herewith.





A simple apparatus for growing organisms under anaerobic conditions. Flasks of about 100 to 150 cc. are seeded and then inverted in jelly glasses to which the usual pyrogallol solution is added.

Test tubes may be inoculated for anaerobic culture, and sealed with any degree of vacuum desired in a preserve jar. Ordinary cultures may be held in like manner for a long time without drying.

Examination of Defective Cans

The procedure in the examination of canned foods in the second class, that is those showing some defect, as distention of the can or change in character of the content, resolves itself first into the determination of whether the contents are sterile or not sterile, and, if not sterile, whether the cause be due to under processing or to leaks.

Defects in cans in which the contents are sterile are springers, flippers, and those which are overfilled or over-stuffed.

Springers

A springer is a can the contents of which are sterile but which has one or both ends more or less convex. This condition is due to overfilling, to generation of gas due to the action of the contents upon the container, to packing the cans cold, or to packing without a vacuum. The condition may be so mild that the ends may be returned by moderate pressure from the fingers or so severe as to cause bursting.

A flipper is the incipient stage of a springer. The term is usually applied to such cans as permit the ends to be returned to the normal by pressure from the fingers or by striking the end of the can on some firm object.

Springers and flippers are almost wholly confined to open top cans, and are most frequent in cans filled cold, as hand-packed tomatoes. The fruit has more or less air or gases incorporated in the interstices of the tissues, and this is retained in the can if sealed cold or given only a light exhaust. The subsequent effect of processing is to break down the tissues and to release the gas which collects at one end of the can. Any subsequent rise in temperature will cause expansion, which produces the convex end on the can. Springers due to this cause tend to become more tense when subjected to moderate heat, as in an incubator, and to disappear on being subjected to a low temperature, as in a refrigerator. It has been a frequent occurrence that foods packed in the North, especially in the fall, and shipped South to a warmer climate have developed the trouble, and when returned to the factory, are found in perfect condition. Likewise the same goods which are perfect in appearance in the winter present the appearance of springers the following summer. If the materials packed were inert toward the can, the springers would remain practically quiescent, subject only to temperature variations.

The effect of the retention of the air in the unexhausted, or very poorly exhausted, can is to increase the activity of the attack by the content upon the metal of the container, and thus liberate hydrogen gas, which further increases the pressure and causes springers of more marked character which will not return to normal by a moderate reduction of temperature or by pressure. It was assumed for a time that because there is always head space in a soldered can the springer was in reality due to overfilling and that the condition could be corrected by leaving head space. Head space, unless the air be exhausted, only aggravates the condition. In the case of the soldered can, the sealing heats the air above the food to a higher degree than is done by exhausting, causing it to be driven out through the vent, which materially corrects the condition.

Springers are also caused by the action of the food material upon the container, a condition independent of the fill or of the exhaust, though slack filling and poor exhausting increase the rate and the amount of activity. (One cubic centimeter of hydrogen is liberated by each 4.8 mg. of tin or 2.2 mg. of iron when dissolved in an acid at ordinary temperature.) The rate of activity is favored by a warm temperature, as stacking the cans while still hot in the warehouse. The cans on the outside of a large stack may be in good condition, while a considerable part of those within, which retain their heat from ten to twenty days or longer, may develop springers or be stack-burned. The storage of canned foods alongside of the boiler room, or in close proximity to steam pipes, when in transit on vessels has resulted in many springers at various times.

If the cans be properly exhausted and stored in a fairly cool place, the development of springers is so slow that most products are consumed before the condition normally appears. Western sweet cherries, plums, and pitted fruits which are not disposed of within the year, are likely to become springers the following season. This appears with such regularity that the condition has been attributed to the germination of the pits, but in no case have we found this condition present.

Springers may be punctured by the method already described, the gas pressure relieved, or a quantity of liquid drained, after which the can will return to a normal condition, be tipped and reprocessed.

Improperly Filled Cans

Distention in cans may result from overfilling or overstuffing and is most frequent in products of a heavy consistency, as sweet potatoes, meats with cereal, and hand packed tomatoes. This occurs almost exclusively in open top cans and when the fairly cool material is forced in at the time of sealing.

A normally filled can is one which is packed as full as possible, but which can be sealed without injury to the product or cause waste, and which will permit the ends of the can to properly collapse after cooling.

An overfilled can is one with insufficient head space to permit the ends of the can to collapse to a normal position. Overfilling is possible but very unusual with hot products, as the contraction on cooling will suffice to permit the can to return to the normal position. Meats and sweet potatoes are both filled as closely as possible in order to exclude the air, as its presence causes darkening and an unattractive appearance. The filling can be successfully accomplished if it be done by weight, or by volume if a plunger be used to press out the surplus. With tomatoes, the object in hand packing is to give an attractive appearance to the fruit, retaining them as nearly as possible whole or in large pieces. Exhausting tends to soften the fruit so that it breaks in subsequent processing. The remedy is to fill properly, though by so doing appearance be sacrificed to a certain extent.

A can which is overfilled behaves in a measure like a springer, contracting and expanding with the lowering or rising of temperature, but more slowly. In the case of heavy products, like sweet potatoes, the contraction may not all be from end to end, and in consequence the ends may remain more or less distended. The argument is made that distention of an overfilled can only occurs when the temperature exceeds that of the food at the time of sealing. This probably would be true for a liquid, if nearly inert or like water, but sweet potatoes which may appear very moist the day after packing may appear quite dry some days later, and there is uncertainty as to whether this redistribution of moisture may not cause some swelling of tissue, and furthermore the strain may not be equally distributed on the can as it would be with liquids.

Overfilling is recognized by excessive weight, by distention of the ends of the can, by absence of vacuum, and by the contents over-running or extending above the level of the normal position of the cover on opening. The contents are normal in character. The strain may overcome the tendency of the end to return to normal and may be a cause of leaks.

In the case of springers there will be no vacuum, the gas given off is hydrogen which will burn, and is emitted with one sudden spurt; the contents are normal and fit for food unless they have been subjected to prolonged heating, as those which have become stack-burned. The cans may show a marked galvanized-like effect or etching, depending upon the kind of product.

The effect of various materials upon the container and the influence of the fill, the exhaust, and the temperature in processing and in storage may be obtained easily by canning water, one per cent brine, carbonate of soda, citric, lactic, acetic, tartaric, and malic acids, filling sets of cans one-third, two-thirds, and level full, filling the solutions at 85°, 150°, and 200° F., and processing at 212° and 240° F., cooling one-half of each experiment and retaining the other half in a warm storage.

A slack filled can is one which is insufficiently filled. This may be due directly to short filling or in some cases to a heavy exhaust. Products which are very dry and mealy may be given the usual fill and the usual exhaust, yet when the cans are opened show an excessive head space. The trouble occurs most frequently with apples, apricots, and Kiefer pears, and is readily demonstrated by placing a glass jar, with the fruit and water under a receiver, and exhausting the air. A quart jar will show a loss of from one and a half to four and a half ounces of liquid which will enter the fruit to replace the air and consequently leave a corresponding space at the top. The slack-filled can, when poorly exhausted, affords the best opportunity for an attack upon the container. Apples and cherries are prone to cause pin holes, and cases in which apricots have cut the tops off at the level of the liquid are known. The percentage of cans which become leakers from this cause is surprisingly large at times. With products which are pre-cooked and properly exhausted, as with meats, the slack filled can is known as a "collapse can" owing to the sides being drawn in to an unusual degree. This applies especially to large cans and to those with straight sides. Fruit and vegetable packers also are troubled with collapsed cans in the No. 5, No. 8, and No. 10 sizes when a heavy exhaust has been used.

A do-over can is one the container of which has been discovered to be defective as soon as it has come through the process and which is mended and reprocessed at once or the contents are transferred to a new can and reprocessed. The do-over is not spoiled food, but is one that may not look so attractive as the regular pack.

A buckled can is one the ends of which have been distended in the process and the panel broken in such manner as not to permit a return to the normal.

Leaks

Defects in cans in which the contents are not sterile due to rupture of the hermetic closure are leaks and are classified as follows: punctures if produced by some object as a nail or tool; body leaks if occurring in the body of the can; top and bottom leaks if occurring in the top or bottom; side seam leaks if occurring in the side seam; cap leaks if around the edge of the soldered cap; tip or vent leaks if occurring at the point of tipping or subsequent venting; and pin hole leaks if caused by the action of the food material upon the container. In the case of open top cans, a leak occurring in the bottom end seam of a can is designated as on the "factory end," while that on the cover is designated as the "canner's end." The difference between the top and bottom of an open top can may nearly always be distinguished by the panels used; furthermore, most manufacturers use some impression to designate their factory end when the cans are made, in order to trace any difficulty which might arise subsequently.

Pin hole leaks are nearly always due to the localized action of the product upon the can. More than 90 per cent occur in the panels or at the margin of the covers where the tin is broken from the steel base, the majority of the other 10 per cent occur at the top line of the liquid in the can. These always occur weeks or months after packing and are not the same as those due to a defective container.

The examination of a can for leaks may be conducted in a number of different ways, depending upon the character of the product, the length of time elapsing after packing, etc.

The first step is to make an inspection of the cans, examining the sides, tops, and bottoms. The plate is examined for holes, all rust spots are pricked with a sharp point, or brushed with a wire brush. Special attention is given to the points at which the plate is bent sharply, as at the ends, and to the creases made by the die, especially if it be sharp. Hard plate has a tendency to be more or less brittle and to break or make very fine fissures, which become the points of attack by the food. It seems illogical to use great care in applying tin, or to use an extra coating of tin and then to nullify the effect by mechanically breaking the coating in unnecessarily sharp bending and by die stamps. Some leaks are due to defective material used and others to defective mechanical construction.

The side seam leaks are usually near the top or bottom, at the point where the overlap is cut away to permit flanging to receive the ends. There is a slight tendency to a decrease in solder at these points and to separating the soldered surfaces in closing the flange or attaching the ends. The side seam is either of the overlapping type, in which one edge overlaps the other and the solder sweated between, or the lock seam in which one end of the body forms a hook to receive a corresponding hook on the other. In this case no raw iron edge is exposed inside the can. In soldered cans the top and bottom edges, cap, and tip are examined carefully. In order to be certain about the adhesion of surfaces, it is customary to tear the lines apart by means of pliers and to note any defective joints.

The examination of the double seam on open top cans is especially important, as this is the point at which most leaks occur. The hermetic closure made by the union of the end with the side is accomplished by means of an interlocking hook, between the elements of which is a thin layer of either a cement substance or paper. Strong pressure is used in driving the metal and cement or paper together to make this joint, and when properly made, it is hermetic, but it requires a mechanic with some skill to keep the closing machine in order, for slight defects are not recognized as soon as they are in soldering. The seams on the two ends are compared for depth from the edge to the end, for the amount of overlap, thickness of the seam, sharpness of turns, and closeness of the overlap to the body. Especial attention is given to the tightness of the seam where it meets the side seam. The examination is continued by filing a section through the seams, using a rather fine, clean cutting file. This will disclose the relative position of parts and closeness of compression. A second test is to file two notches about a half inch apart, and then the outer sheet of tin between these points. A little pressure exerted upon this outer portion will detach it from its position and reveal very clearly the length of the different members of the double seam. Leaks at the double seam are due to an imperfect gum or paper gasket, to improper adjustment in height so that the cover and body do not make a good hook, to a loose first roll which does not turn the edge under properly, and to lack of adjustment in the second roll so that the parts are not drawn together tightly.

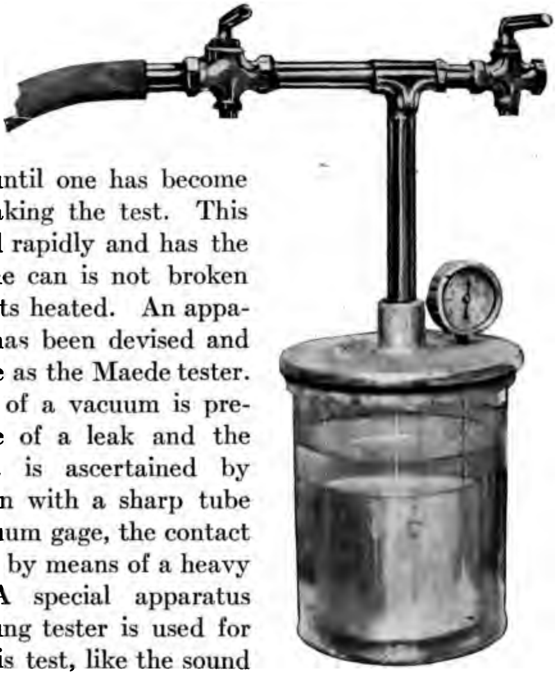
Tests for Leaks

1. The simplest test for a leak is by tapping the end of the can with a metal bar. This test is used in a very large number of warehouses and, while not conclusive, it is strongly indicative of the presence of a leak or defect. A can with a normal vacuum will give forth a pitch or musical sound quite different from a can in which the vacuum is lost. The difference is best learned by testing a number of cans and then puncturing the side near the top and closing and repeating the tapping. The test is most applicable shortly after canning, and is used by the workmen when labeling or boxing the goods.

2. Another simple test for a leak, and one nearly always available, is to drop the can in a pan of boiling water, or into a boiling salt solution. The pressure generated within a can by boiling water will generally be between thirteen and fifteen pounds, or sufficient to cause a stream of bubbles to issue from the leak. The hot water has the advantage of removing any gummy substance which might obstruct the opening. The pressure generated in salt water at 225° F. will be equivalent to about 19 pounds.

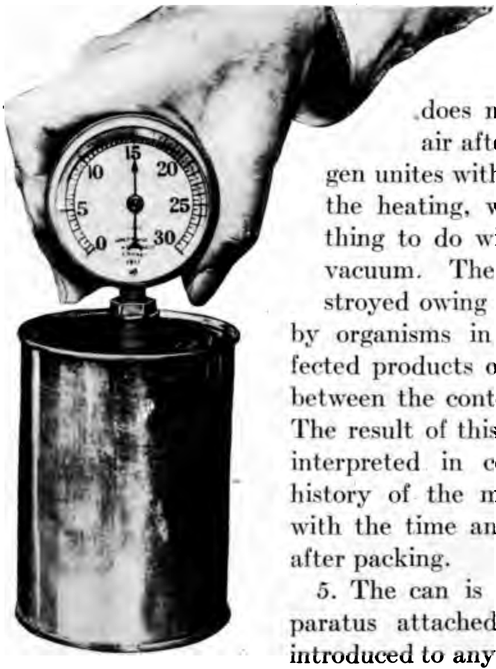
This method has the advantage that the contents of the can are not lost as the case is when a puncture is made. The method is not infallible, but it is simple and merits more attention than it has received.

3. A method of determining leaks is to immerse the can in water in a heavy glass jar, and then to apply a vacuum to the jar. A twenty-nine inch vacuum is equivalent to creating an internal pressure of more than fourteen pounds and will cause the gas which may be present to break through any ordinary leak. There is always a certain amount of air caught under the edge of a double seam and this may be mistaken for a leak until one has become accustomed to making the test. This test can be applied rapidly and has the advantage that the can is not broken nor are the contents heated. An apparatus to do this has been devised and is sold to the trade as the Maede tester.


The Maede vacuum testing apparatus. The can to be tested is submerged in water in a heavy glass jar and a vacuum applied.

4. The absence of a vacuum is presumptive evidence of a leak and the condition present is ascertained by puncturing the can with a sharp tube attached to a vacuum gage, the contact being made secure by means of a heavy rubber shield. A special apparatus known as the Young tester is used for this purpose. This test, like the sound test, is used for its indicative value and is most useful at the factory. All products should have a vacuum, the amount depending upon the fill, the temperature at which the cans are sealed, and the temperature at which the test is made. Most canned foods exhausted at a temperature of 130° F. and tested at 85° F. will show about four inches of vacuum. The processing of almost all foods, even though sealed cold, will cause a slight vacuum, from one to three inches. It has been stated that

any air incorporated with a food substance when the can is sealed does not continue to exist as air after processing. The oxygen unites with other materials during the heating, which may have something to do with the formation of the vacuum. The vacuum may be destroyed owing to the formation of gas by organisms in understerilized or infected products or to chemical activity between the contents and the container. The result of this test must therefore be interpreted in connection with a full history of the method of packing and with the time and conditions of storage after packing.


The Young vacuum testing apparatus.

5. The can is punctured and an apparatus attached by which air may be introduced to any desired pressure. This is the test most relied upon by the can manufacturers for checking the work done while adjusting machines in canneries. It is also used extensively in laboratories. The special apparatus used consists of a puncturing pin which automatically makes a tight joint with the can, a pressure gage, and connections for a hand bicycle pump or other air pressure. The punctured can is submerged in a bucket or jar of water, the air pressure applied, and if a leak be present, bubbles will be emitted at that point.

The standard apparatus for puncturing and using pressure to test cans.

There is considerable controversy as to how much pressure should be used in testing cans. As the greatest pressure which can be exerted inward to carry germs inside can only equal the atmospheric pressure, about 14.7 pounds, it is argued that this should be the limit of pressure used. Those who maintain that a higher pressure should be used contend that a minute leak which may have been developed by atmospheric pressure when the can was cooling, and admitted air or organisms, may become closed by the product and a much higher pressure be required to reopen it. It is well known that the fissures which will admit air are so small that an empty dry can may be pumped up and leak on a pressure of less than ten pounds, but if only sufficient water be introduced to wet the whole of the inside it may resist a pressure of more than fifteen pounds.

In order to make this pressure test more nearly certain, it is sometimes necessary to make a hole in the end of the can and clean out the contents, then wash the inside thoroughly, or scald it with an alkaline solution, and when dry, reseal the opening, and test in the usual way. The object is to effectually remove any material which may have plugged the hole.

6. An aniline dye is added to water in the cans, then sealed and the cans placed in a bucket of water while processing in an open bath or retort. The pressure generated within the cans will cause leakage to the outside and discolor the water in the pail.

7. Cans containing hot water are submerged in a pail of cold water containing the dye to cause the latter to be drawn through any opening on cooling, and, when cold, examination made for the entrance of any color.

8. Cans containing a strong volatile substance are heated and the presence or absence of the characteristic odor is noted.

9. Some nutrient medium, preferably bouillon, is placed in the cans, sterilized in the usual process, and while hot the cans are dropped into a cold solution containing a heavy growth of some organism. If peas are being canned, pea bouillon is made and one portion placed in the cans and sterilized, the other portion inoculated with the organisms, which cause swelling or souring, and used as a cooling medium. A similar plan is followed with other products. A leak would be indicated by the organisms entering during the cooling process.

10. A bacteriological examination to differentiate between organisms which may be present due to under sterilization and those which gain access from the air may be used. Practically all leaky cans become infected, especially if moved, and there is generally more than one form of organism in large numbers. The notable exception to this rule is when cans are cooled in a tank and the water becomes strongly infected with some organism, particularly

if it be an acid producing type. These may be so vigorous and cause such a change in the food as to render it unfavorable for growth of other forms. A second differentiation is to determine whether the organisms are aerobic or anaerobic. Aerobic forms usually predominate in leaks and anaerobic forms in cans which do not leak. The bacteriological tests while not absolute are sustained in more than 95 per cent of cases where goods have been packed experimentally, one part made tight and underprocessed, and another with loose seams which would hold only about two pounds pressure.

Some of the above methods are more theoretical than practical, but they are presented because they have been used and represent efforts at getting at the truth.

In addition to the foregoing tests, an examination of the contents of the can for color, and of the interior of the can for evidence of attack by the contents upon the container is important. The admission of air causes the contents, in almost every instance, to become darker and to increase the action of the food product upon the tin. This evidence, while it does not locate a particular place where leakage may occur, becomes strongly corroborative.

If a given case of spoilage be found to be due to leaks, there still remains the tracing of the cause to its source. It may be bad cans due to defective material, as too hard and brittle plate, to bad machine work at the factory, to bad adjustment of the double seamer in the cannery, to dropping cans in vertical or steep runways, and to mismanagement of the process. The evidence of bad materials and factory workmanship is shown in body and end pinholes, in leaks at the factory end and side seam; the bad adjustment of the double seamer is shown in the frequency of the leaks on the canner's end and splits at the double seam. The damage done by mismanagement in processing is due to subjecting the cans to unnecessarily heavy strains.

Pressure in Cans

The internal pressure in cans is due to the expansion of the contents by the difference in temperature at the time of sealing and when the highest point is reached in processing. These differences cannot be set forth in a table with anything like exactness, as the container itself is not rigid and the ends or sides may spring sufficiently to make appreciable changes: the contents vary a great deal, so do not follow the known laws for water or saturated vapor, though the majority of foods, especially those which have been pre-cooked, closely approximate the changes for water. Gases incorporated in the tissues of fruits and in cold storage products cause a decided increase above the normal pressure in processing. The usual quick heating or mechanical exhausting may not release these gases, which may account for the buckling of some cans and the irregular vacuum when the product is cooled.

The expansion of water as affected by temperature is shown in the following table from Kent (column four showing increase in volume for No. 2 can is added).

Expansion of Water

Centigrade	*Fahrenheit*	*Volume*	*No. 2 can* cc.
4	39.1	1.00000	
5	41.	1.00001	
10	50.	1.00025	.15
15	59.	1.00083	.5
20	68.	1.00171	1.
25	77.	1.00286	1.7
30	86.	1.00425	2.5
35	95.	1.00586	3.5
40	104.	1.00767	4.6
45	113.	1.00967	4.8
50	122.	1.01186	7.5
55	131.	1.01423	8.5
60	140.	1.01678	10.
65	149.	1.01951	11.7
70	158.	1.02241	13.4
75	167.	1.02548	15.3
80	176.	1.02872	17.2
85	185.	1.03213	19.3
90	194.	1.03570	21.4
95	203.	1.03943	23.7
100	212.	1.04332	26.

The following table[1] giving the atmospheric and absolute pressures of saturated vapor at different temperatures within the range of food preserving will serve as a basis for estimating the pressure in cans.

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[1] Table with exception of Centigrade column from Mechanical Engineers' Pocket Book, 8th Edition, Kent.

PROPERTIES OF SATURATED STEAM

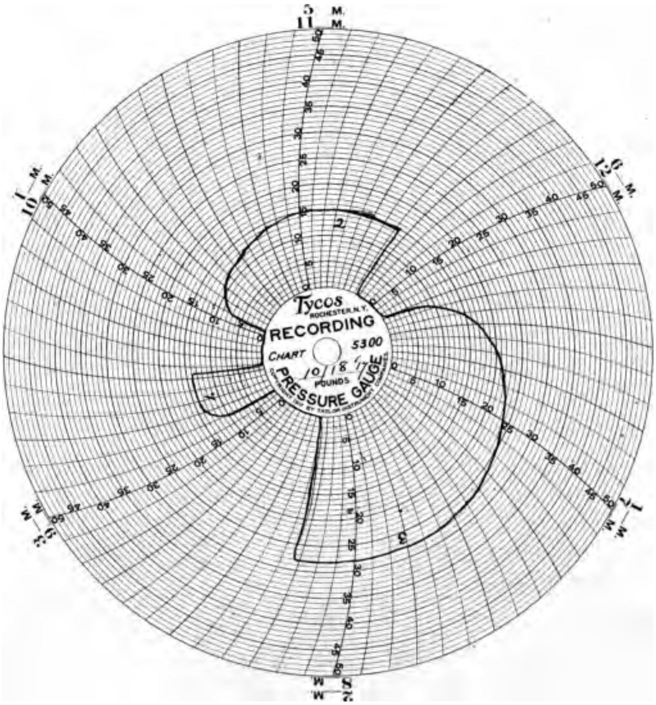
Vacuum	*Absolute pressure. Pounds per sq. in.*	*Temperature Fahrenheit*	*Temperature Centigrade (Approximate)*
29.74	0.0886	32	0
29.67	0.1217	40	4
29.56	0.1780	50	10
29.40	0.2562	60	16
29.18	0.3626	70	21
28.89	0.505	80	27
28.50	0.696	90	32
28.00	0.946	100	38
27.88	1.	101.83	39
25.85	2.	126.15	52
23.81	3.	141.52	61
21.78	4.	153.01	67
19.74	5.	162.28	72
17.70	6.	170.06	77
15.67	7.	176.85	80
13.63	8.	182.86	84
11.60	9.	188.27	87
9.56	10.	193.22	90
7.52	11.	197.75	92
5.49	12.	201.96	94
3.45	13.	205.87	96
1.42	14.	209.55	99
0.00	14.70	212.0	100
0.3	15.	213.0	
1.3	16.	216.3	
2.3	17.	219.4	
3.3	18.	222.4	
4.3	19.	225.2	
5.3	20.	228.0	
6.3	21.	230.6	
7.3	22.	233.1	
8.3	23.	235.5	
9.3	24.	237.8	
10.3	25.	240.1	
11.3	26.	242.2	
12.3	27.	244.4	
13.3	28.	246.4	
14.3	29.	248.4	
15.3	30.	250.3	
16.3	31.	252.2	
17.3	32.	254.1	

If a dry No. 2 can be sealed at room temperature, 75° F., and be immersed in boiling water, a pressure of about 4.8 pounds will be generated, which corresponds as closely as may be expected (considering the yielding nature of a can and coarse reading of a pressure gage) with the theoretical expansion of the air, 1/491 for each degree F. (or 1/273 for each degree C.). If the can be filled one-fourth full of water at 210° F., and sealed, it will yield a pressure of about 9.4 pounds at 212°; if one-half full, it will yield 7.2 pounds; and if three-fourths full, it will yield 4.5 pounds. If, however, the can be at room temperature and one to five cubic centimeters of water be introduced, the pressure will be slightly less than 15 pounds at 212°, and the same will hold for any quantity of water added, unless the can be filled so that no air space remains, then the pressure will be about 25 pounds.

The pressure within the cans does not follow the rise of temperature of the water content. There is first a sudden rise due to heating the gas and then a very gradual rise with the heating of the contents; and the reverse operation follows on cooling. A can submerged in a water bath and raised so that only the top projects above the surface will show an instant drop of pressure, usually from three to six pounds.

The external pressure is the atmospheric or retort pressure and operates to produce leaks or strains according to the vacuum present. Nearly all foods are exhausted either by heat or by mechanical means. The former is the most common. The effect produced by heating No. 1, No. 1 flat, No. 2, No. 2 1/2 cans, and cans not exceeding these in volume or in diameter is about as follows: cans exhausted at 100° F. and cooled to 85° F. will show about one inch; 120°, 2 inches; 140°, 4.5 inches; 160°, 8.5 inches; 180°, 12.5 inches; 200°, 16.5 inches; and 210°, 21 inches. Cans of larger diameter or of soft plate give very irregular readings owing to more or less collapse of the body. Likewise products which are heated quickly or unevenly, or vacuumized quickly in a machine show variations due to not removing the incorporated gas.

The pressure observed in canning fruits and vegetables which have been pre-cooked follows very closely the pressure obtained in heating water. In canning raw fruits and vegetables there are some variations not easily accounted for but which may be due to defective technique in obtaining exact data. Fruits with slight spoilage, and cold storage fruits and meats give higher pressures than the fresh. In berries, fermentation so slight as to be scarcely recognizable may add five pounds to the pressure record, and slightly soured squash has shown an increase of twelve pounds.



A record of the pressure developed in cans during processing. No. 1, water, can sealed at 100° F., bath 212° F. No. 2, squash at the same temperatures. No. 3, squash which had begun to ferment, using the same temperatures.

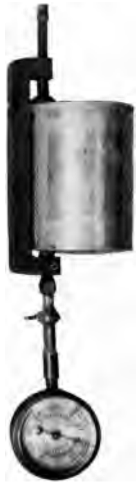
This line of investigation has not been conducted upon a sufficiently broad scale to more than indicate the variations without affording a conclusive explanation.

If the cans be processed in a high temperature open bath, pressure is increased with the temperature, at 245° F. being about 27 pounds. If processed in a retort, the internal pressure equals the pressure acquired in raising to 212° F. plus the pressure in the retort, but the excess above that at 212° is counteracted by the external pressure on the can until the steam is turned off and the kettle opened or "blown off," then the pressure will be the same as in an open bath at the same degree. If the retort be allowed to cool down without blowing, the internal can pressure will only slightly exceed that reached at 212°. If, however, cold water be turned in at the top of a closed retort, it condenses the steam which is present and causes a partial vacuum, and to that extent increases the internal pressure on the can.

If, however, air or water pressure is placed upon the cans as the steam is turned off, the effect of internal pressure may be counteracted or overcome. It is therefore obvious that perfectly good cans may be so handled in the processing as to cause unnecessary strains and breaks and this is more liable to occur in No. 3 and larger cans, furthermore, by very slow handling of the retort or the use of air or water pressure, cans of any size may be processed without injury.

The foregoing explanation of internal pressure may also be applied to buckling; No. 2 cans buckling with a pressure of about 28 pounds, No. 2-1/2 cans with a pressure of about 20 to 22 pounds, and No. 3 cans with a pressure of about 18 to 20 pounds.

The pressure generated in cans during processing and also during spoilage is obtained by means of a simple apparatus, consisting of a clamp, a stuffing box for a hollow puncturing pin, a pad to make a tight joint with the can, and a pressure gage attached to the pin. The bore in the pin is made small so that any error in expansion will be reduced to the minimum. The can may be suspended in the bath or the pin may pass through a hole in the retort, and the record obtained on the outside. A T fitting may be inserted below the gage and used for introducing pressure into the can, for exhausting the air or removing gas. A special recording device has also been devised to do this work.



A simple apparatus for obtaining the pressure in cans during processing or from spoilage.

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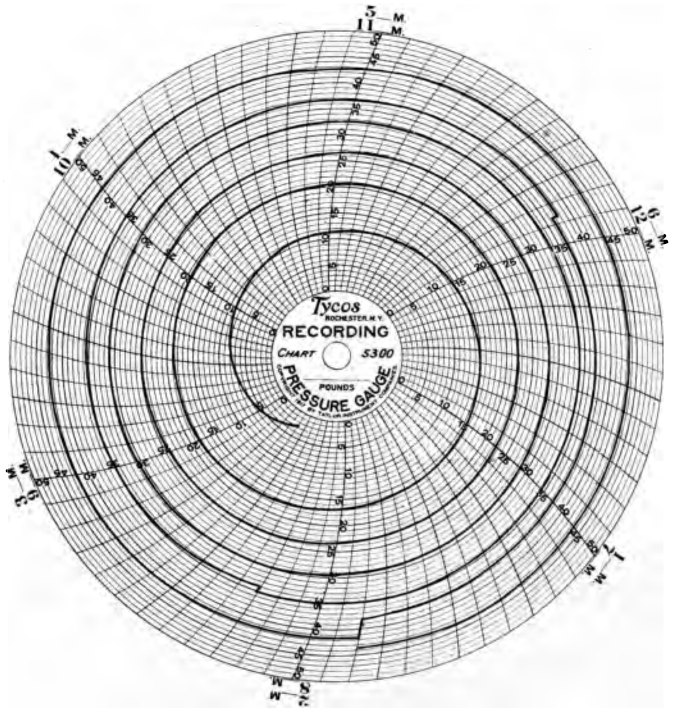
Swells and Flat Sours

Defects from lack of sterilization are designated in the trade as swells or puffs and flat sours, though this classification is not strictly correct. A food may not be sterile and spoilage may be very pronounced without the production of gas or the development of a sour taste.

A swell is a can having one or both ends or some part of the body distended by pressure generated by gas-producing organisms.

A flat sour is a can in which the contents have been changed, usually with an increase in acidity, but without the production of gas or of only a very small quantity. The exterior of the can presents a normal appearance.



A typical record of the gas pressure developed during the swelling of a can of corn. The small drops in pressure are due to sudden distention of the end, and in one case to buckling. The limit of pressure obtainable with the apparatus is 50 pounds. By relieving the pressure when this point was reached and repeating, almost duplicate charts were obtained on the same can for eight consecutive days. Each revolution of the chart represents six hours.

Swells developed from under-processing generally appear shortly after packing, sometimes by the second day, very frequently by the fifth day, and practically the entire trouble may be over by the fifteenth day. If the cooling has been quite thorough and the storage fairly cool, the development may be delayed several days or even weeks. Products of a heavy consistency and having no free liquid, thus localizing and retarding the growth of bacteria, develop trouble much more slowly, and may not be recognized until the goods have been distributed in the trade.

Swells are most often associated with rush operations in canning. The stock comes to the factory in unusual quantity; the operations are speeded up, the usual time not being allowed for raising the temperature in the retorts nor in blowing off, which has the effect of decreasing the time of cooking. Changes in the consistency of the syrup or sauce have an influence upon the time of heat penetration in the can, and if heavy, may cause spoilage. Corn which has become starchy or pumpkin which has been cooked too dry may not be sterilized by the regular process. Swells are very prone to occur in well ripened tomatoes and fruits. The green fruit has sufficient firmness to permit the hot juice to flow between the pieces and the heat to be distributed, while the soft material soon forms a mass and prevents heat penetration. Contrary to general belief, green fruit is more easily sterilized than the ripe.

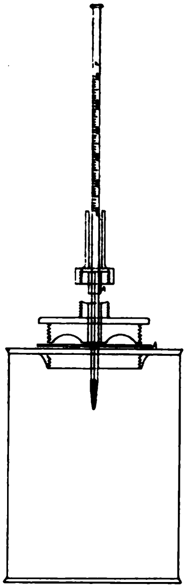
The flat sour gets its name from the fact that the can shows no distention and the food develops a very sour taste due to the formation of acid. This condition is not recognized nearly so early as the swell, due to the fact that there is no external evidence of trouble to attract attention. Furthermore, the breaking down of tissue and the formation of acid is a slower process than that of the gas formation. Flat sours are rarely recognized under two weeks and frequently not until after a month. If the trouble be due to thermophilic forms, then storage of only partially cooled cans in a warm warehouse will favor the development.

Flat sours are generally associated with delays in handling foods through the factory, as cut peas or jerked corn permitted to stand in the yard or under the shed over night and to become more or less heated. It is possible to have corn and peas sour so slightly before packing as to be unnoticed, but later the heat of the process develops a distinctly acid taste. This is not a real flat sour, as the number of organisms are relatively small and are killed during processing, and a flat or an acid taste is present from the start. In flat sours the number of organisms is always high though they may not retain their vitality for a very long time. Lack of cooling and stacking cans while hot are the chief causes of flat sours. The cans which might be sterile if cooled may not be sterile if not cooled, and this is true particularly if the process is close to the minimum line. This corresponds with making media in a laboratory, where experience has shown that tubes or flasks left in the sterilizer and which cool slowly are prone to spoil, while those taken out and cooled remain perfect. A method of testing for flat sours without opening the cans is to submerge them in hot water until the ends spring out and then lay them on a table to cool. The ends of the normal cans will collapse in a short time while the defective will not collapse or will do so more slowly.

Heat Penetration in the Can

The greatest factor affecting understerilization is the consistency of the material being canned. The time required for heat to penetrate from the outside to the center of a can varies through very wide limits. A can containing a liquid, like apple cider, will require the minimum of time for the heat at the center to very closely approach that of the surrounding bath, as its conductivity is about the same as that of water. A can of pie-packed sweet potatoes will require about the maximum time to accomplish the same result. In experimental work it was found that the heat at the center of a No. 3 can containing water was raised from 85° F. to 210° F. in about 4 minutes after being dropped in the boiling water. The sweet potato may require from three to four hours to reach a temperature above 200° F., and generally does not come within ten degrees of that of the bath during the usual process. In the former case, convection currents are established and the heat is conducted rapidly; in the latter no convection currents are present, and the broken, homogeneous mass acts almost as an insulating material for the central part. Differences in heat penetration due to the use of sauces, of seemingly only slight difference in consistency, as in baked beans, in adding purée to tomatoes, in the starchy consistency of corn, and in the matting together of well-ripened fruits, may produce very appreciable differences in the time required for heating, thus exceeding the factor of safety generally allowed. When two packers living in the same locality report the use of two rather widely different processes for the same product, the necessity for the measure will generally be found in the difference in the product. When a packer experiences sudden and unusual spoilage, the first inquiry will usually develop a change in consistency. The difference in time for heat penetration in a medium and a heavy body in Maine style packed corn may make a difference of thirty minutes for the temperature to reach the same degree. In factories there is little attempt to follow these variations closely, the practice is to give all foods an excessive process.

In order to assist the heat penetration in the cans they may be agitated or rolled, thus not only reducing the time required for sterilization, but securing a much more uniform cooking of the entire product. This method is not applicable to all products, but is of great practical value with those composed of a mixture of solids and liquid, like fruits and tomatoes, and those of heavy consistency, like squash. It has been found that most cans should make about twelve revolutions per minute to insure agitation, that rolling less than seven revolutions gives but little better results than when standing, and that more than fifteen revolutions may injure delicate products, like soft fruits and berries.



A simple arrangement for getting the temperature at the center of the can.

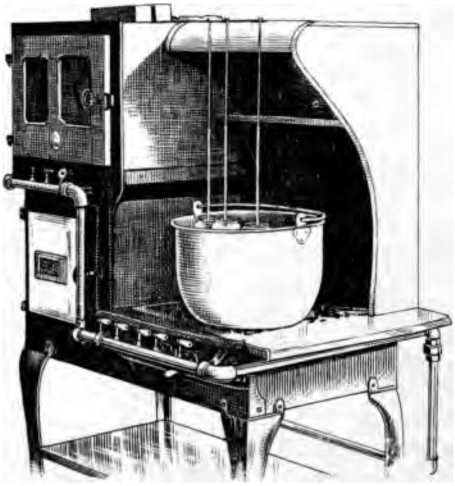
A simple method of determining the temperature in the center of a can in experimental work is to have a cap made with an opening for a thermometer, a packing box, and a protective collar. A hole can be made in the regular can cover and this special cap soldered in place. A nitrogen filled thermometer with a long stem to reach the center of the can is set in place, the joint made tight by means of a gasket and the screw collar. A can with a special screw cover is used for convenience when many tests are wanted. The advantage of this method is that the can may be held in any position, remain standing or be rotated, and the temperature be read at any time. The older method consisted in placing a maximum self-registering thermometer within the can, but the only information acquired was the maximum temperature reached, not when it was reached. The writer had a thermocouple constructed in 1907 which recorded the temperature when the can was in a retort as well as in the open bath, and although much information was developed, the apparatus was too delicate for practical purposes. The work was repeated in 1914 to study the variation in temperatures in different parts of retorts. A mercury recording thermometer is now available for use in cans while in the bath or retort, and is a regular

A recording thermometer now used by some packers to obtain the temperature within the cans. The record is only approximate, but is valuable in supplementing that obtained on the bath. The bulb and fitting for the can are smaller than illustrated.

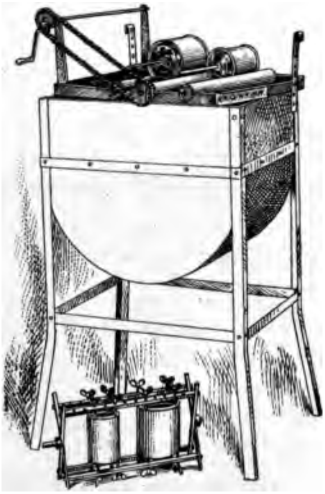
part of the factory equipment for this work. One of the advantages of the simple thermometer described is that it presents the minimum of conductivity of external heat to the bulb, and therefore gives a fairly accurate record.

Thermometers should be suspended so that the bulb will be slightly below the center of the can in all experiments involving temperature in large jars such as the quart and half-gallon used in home canning.

The effect of agitation can be demonstrated quite easily with very simple apparatus, such as two cans with thermometers, one placed in a bath atrest and the other tied in a wire frame provided with a handle so that the can may be rotated or shaken, and a kettle to hold water, salt, brine, or heavy mineral oil. The kettle should contain about eight or ten times as much liquid as does the can. A more pretentious device for rolling cans is illustrated.



A simple device for studying heat penetration. Glass or tin containers may be used, closed or not closed, and at any desired range of temperature.



Apparatus for studying the effect of heat penetration in cans when standing and when agitated, the agitation produced by rolling in one direction, or backward and forward, or turning end over end, and at constant or varying speeds.

The claim is made that the reason why home canning is conducted successfully at a temperature lower than that found necessary in commercial work is that in the latter the cans are closed during processing and the organisms are killed less readily. In

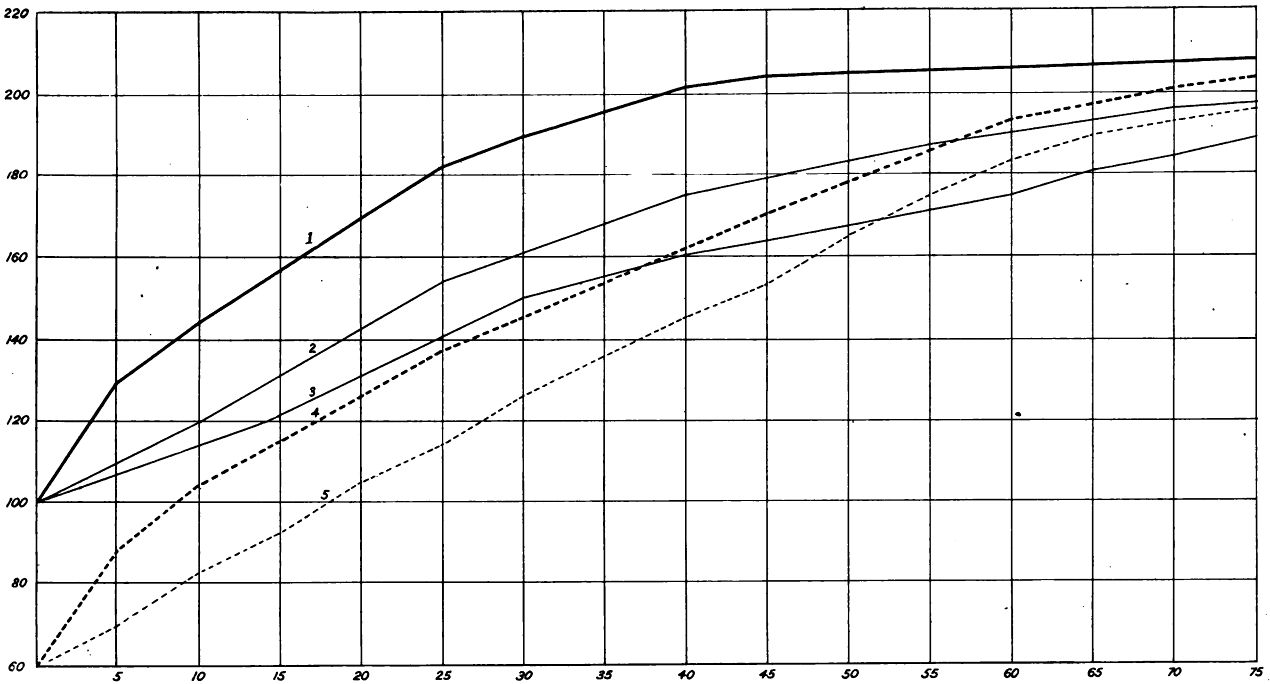


Diagram showing the rise of temperature in water in a 20-quart kettle or wash boiler and of contents of quart cans. The temperature of the water and of the contents were identical at the start; the heating was accomplished over an ordinary gas burner on a kitchen range. The temperature in half gallon cans is not shown, but was from one to three degrees less than that for quarts at the same intervals.

No. 1, water in the bath; No. 2, blackberries packed in water; No. 3, blackberries packed in 50° syrup; No. 4, water in the bath; No. 5, water in a quart jar. Temperature of the bath 212°F. Time 75 minutes.

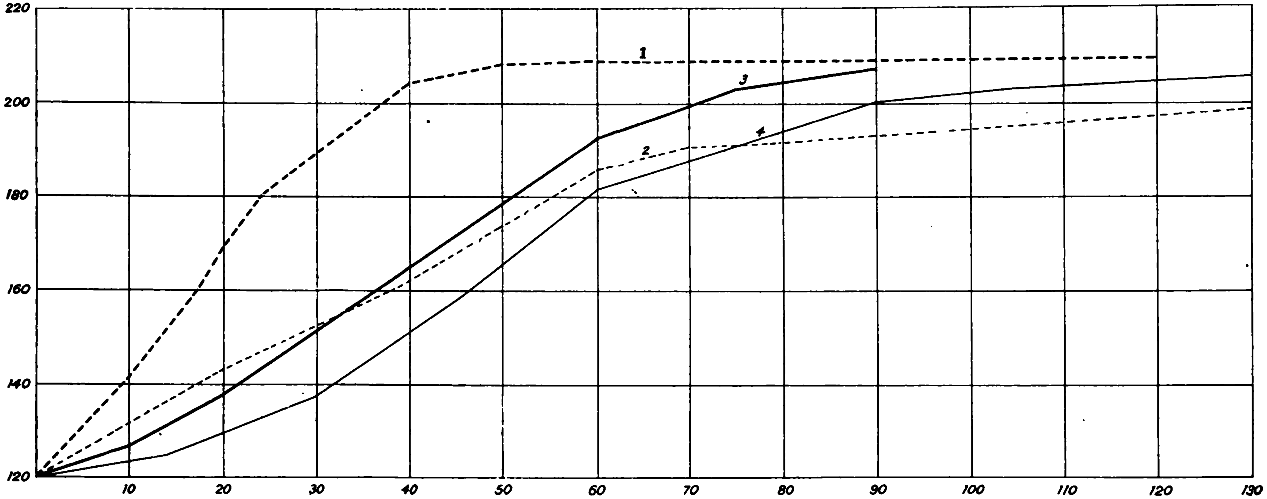


Diagram showing the rate of heat penetration in pumpkin and sweet potatoes when standing and rolling, No. 2½ can. No. 1, pumpkin rolling; No. 2, pumpkin standing; No. 3, sweet potatoes rolling; No. 4, sweet potatoes standing. Temperature of the contents, 129° F., and of the bath, 212° F. Time, 130 minutes.

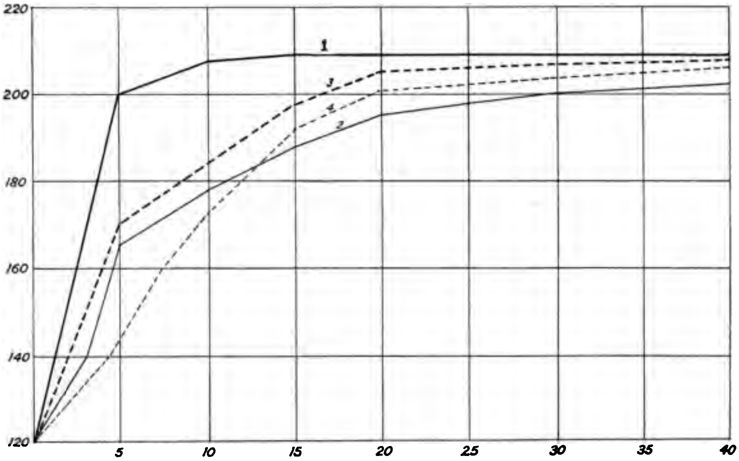


Diagram showing the rate of heat penetration in tomatoes and tomato pulp (1.034) when rolling and standing. No. 2½ cans.

No. 1, tomatoes rolling; No. 2, tomatoes standing; No. 3, tomato pulp rolling; No. 4, tomato pulp standing. Temperature of contents, 120° F., and of the bath, 212° F. Time, 40 minutes.

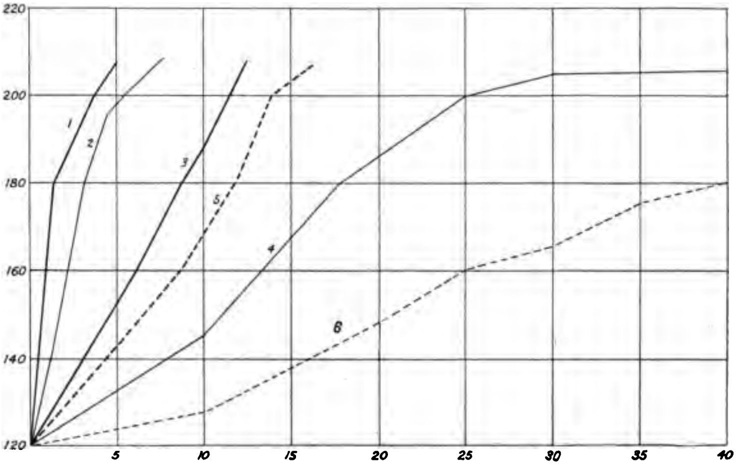


Diagram showing the rate of heat penetration in syrup, prime ripe peaches, and over ripe peaches when rolling and standing. No. 1, syrup 50°, rolling; No. 2, syrup 50°, standing; No. 3, prime peaches, rolling; No. 4, prime peaches, standing; No. 5, soft peaches rolling; No. 6, soft peaches, standing. Temperature of contents, 120° F., and of the bath 212° F. Time, 40 minutes.

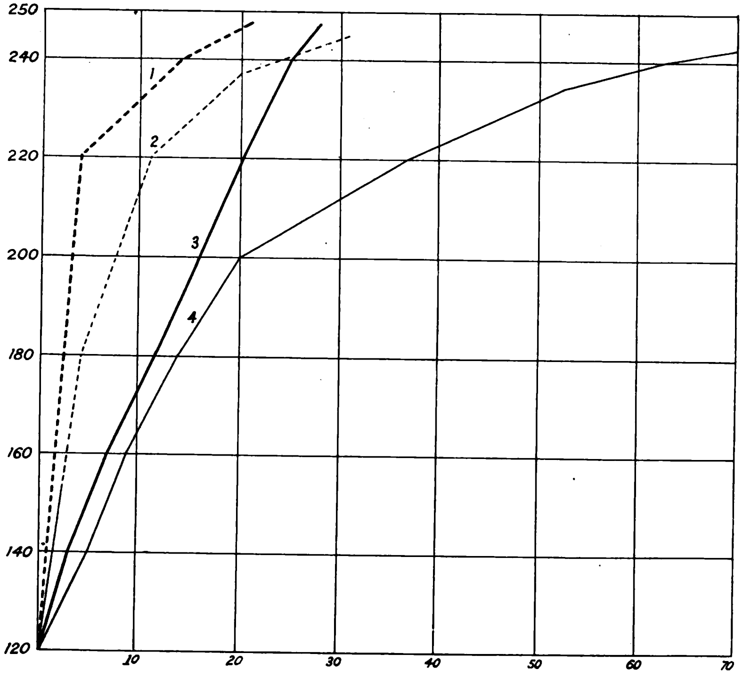


Diagram showing the rate of heat penetration in peas, whole grain corn, and cream corn, when rolling and standing.

No. 1, peas, standing; No. 2, whole grain or Maryland style of corn, standing; No. 3, Maine style or cream corn, rolling; No. 4, Maine style corn, standing. Temperature of the contents 120° F., and of the bath 250° F. Time, 70 minutes.

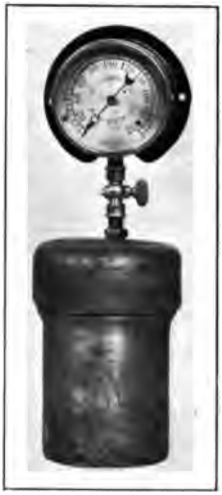
experiments carried out with some of the cans sealed and some with a vent open, but which was closed after processing, no difference was noted in the percentage of spoilage.

It is a matter of observation that cans which are only partly filled spoil more readily than those which are well filled, and in the case of fruits, moulds may occur in the partly filled cans and develop in a vacuum as high as nineteen inches.

Organisms in Spoilage

The biological study of the organisms causing spoilage has received a remarkably small amount of attention considering the importance of the subject and the ease with which material may be secured. The majority of the losses are due to bacteria, occasional losses in fruits may be due to yeast or to mould, but these are the exception. It has been assumed that mould will not fruit in the absence of air, and that the presence of spores is proof that a leak must be present. This is not strictly true, as fruiting mould has been observed in cans which have shown as high as 17 inches of vacuum or about all the vacuum that is practicable to obtain in a can by heat exhaustion under factory conditions. Among the bacteria, the large bacilli of the lactic acid type are probably the most numerous, though very small forms and cocci are numerous, especially when decomposition is associated with foul odor. Anaerobic forms are predominant in underprocessed goods.

Thermophilic forms apparently similar to the soil types are frequent and usually overlooked unless given a long and high incubation. The occurrence of forms which are not distinguishable from B. tetanus, B. botulinus, and actinomyces in morphological characters and staining, is common in some vegetables. Some organisms produce great quantities of gas, others a relatively small amount, and some either none or only a trace. Some vigorous growers will produce sufficient gas to cause No. 2 cans to burst, which on an average is about fifty pounds pressure, but the majority have their growth or physiological activity arrested by pressures below 30 pounds. Unfortunately, there has been little cooperative work between bacteriologists and chemists in determining the character of this gas and other decomposition products resulting from the metabolic activities of the organisms in canned foods. The changes induced in the product are usually bleaching and softening of the tissue, though these are not constant: peas may turn dark or even black, occasionally corn blackens, shrimp and lobsters often blacken. Liquefaction of heavy products, such as corn, pumpkin, milk, meats, and fish, is common. The odor and taste are affected in advanced stages. In the case of sweet potatoes and similar heavy products without free liquid the action may be localized. The production of poisonous products by bacterial activity in canned foods has been very generally assumed, but the evidence to support the assumption is rather meager.



Apparatus for obtaining the maximum pressure of gas generated in swelling. The can is enclosed in the iron cylinder and the unoccupied space filled with water.

Nearly all cases of spoilage due to under-processing develop the very practical question, what is the safe process for the given line of foods? One can always sterilize, but to do so at a temperature and within a period which will produce the best quality and at a reasonable cost is a commercial necessity that must be met. The answer is therefore one which must be based upon packing experience, as we are lacking in the primary fundamentals, that is, a knowledge of what organisms are normally present and that cause spoilage, and what is their thermal death point. We do not know whether the same organisms are present in all parts of the country, whether their resistance is greater during some seasons than others, or whether the resistance may vary during the same season. During the past year, we observed that spinach, beets, potatoes, and onions packed early in the summer kept at a much lower process than those packed in the fall. The statement has been made to canners that new and more resistant strains of bacteria are developing, and that under unusual seasonal conditions the resistance of known forms may be heightened. It has even been claimed that new organisms have been introduced into localities by commercial fertilizers which later caused spoilage. These claims are usually based on the fact that in a cannery where packing has been done for a number of years, and in which the same formula and process have been used, suddenly a heavy spoilage develops, the conditions being accepted as proof that some new germ has invaded the premises or that an old one has developed unusual resistance. The evidence to support these beliefs is not very conclusive. This much is known, that peas are sterilized in New Jersey in a shorter period than in Wisconsin, and in the latter state in less time than in New York. It is known that with peas and corn the temperature must be increased or the time prolonged slightly as the season advances; also that peas and corn left standing in the yard or shed for some hours or over night must be given a heavier process than perfectly fresh stock. The same organisms which cause the spoilage can be found in the pea viner or the grader, and on the corn cutter and silkers, though not in such large numbers, when any peas or corn are being threshed or cut. Theoretically the temperature which will kill in one instance should destroy in the other, but here theory and practise do not agree.

The length of time organisms retain their vitality in the cans seems to vary within wide limits. The writer has had peas and corn from which cultures were obtainable seven years after packing, while in other cases, with the same products, no growth could be obtained after fifteen days. Very vigorous gas production may take place in a product and then suddenly cease and within a few days no living organisms be found. The reasons for these sudden changes in vital activity and even the disintegration of the bacteria themselves, are not known, they are merely surmised. There is no relationship between the number of organisms found either by the plating method or direct counting and the amount of gas or acidity produced.

Material for the study of several varieties of organisms, their biological activity, or the conditions affecting sterilization are always available for study. White beans, dried lima beans, kidney beans, dried peas, wheat, corn, potatoes, onions, and roots will provide all the variety needed when the green stock is not upon the market.

Determining the Character of the Product

The bacteriological examination of canned products to determine their fitness for food is confined almost wholly to tomatoes, and tomato products as pulp, purée, and ketchup. Some attempts have been made to extend the examination to other products, as butters, jams, jellies, and preserves, but almost nothing has been done with whole or cut fruits and vegetables. The procedure in determining wholesomeness is different from that for sterility as, in the former, one must deal with the dead organisms and is limited almost wholly to what may be seen under the microscope. It is most unfortunate that no satisfactory method has been developed to determine the presence of unfit material, as the purchaser has no means of judging from looks, taste, or smell what may have entered into these comminuted products. In the whole or large piece stock, he can judge by the gross appearance with a fair degree of accuracy. We are lacking in the fundamentals necessary for a proper examination: that is, what constitutes the normal flora upon fully matured products, the abundance to which they attain under varying conditions, and what organisms cause the changes which are generally recognized as decomposition. Berries picked from the bushes, grapes taken directly from the vines, and orchard fruits from the trees or picked up from the ground are eaten without washing, and are not considered to be filthy, putrid, or decomposed. The careful washing of these berries and fruits will remove some of the organisms from the surface, but does not change the status of the product. If skins are wholesome when upon the raw tomato, prune, and raisin, they are not made filthy by the simple process of cooking. The skins are always covered with enormous quantities of organisms, especially when the fruits are well ripened and during warm moist weather. If the fruits be peeled, the inner portion will have a relatively smaller number of organisms, but if this outer portion were fit for consumption while on the fruit, it certainly has not been changed by mechanical separation from it, and a product made from it is not filthy, putrid, or decomposed simply because it has a relatively greater number of organisms than the body material. The enologist has recognized for a long time the importance of the growth of certain forms of yeast upon the skins of grapes in order to produce high quality in wines. He has recognized these as being a normal flora upon the grape and that they may be present in great numbers. He has also recognized the presence of other forms and of torulae to be destructive and undesirable invaders. If the number of organisms were the sole criterion by which the grapes were passed as sound or unsound, it might be the means of rejecting the most desirable and retaining the defective. We happen to know about the wine grape because it has been an object of special study, but are without corresponding facts on other fruits.

The processes used in manufacturing a product may exert a very marked influence upon the number of organisms which may be estimated to be present. A tomato, for example, if hard ripe packed whole in water, and processed at a low temperature, will give the minimum number of organisms in a microscopic field, for only the liquid portion can be examined and all but a few of the organisms will remain adherent to the tissue. The riper the fruit and the more it is broken by cutting and tearing and the more finely it is comminuted, the more nearly perfect will be the distribution of organisms and the opportunity for seeing them in the microscopic field. The comminution, whether it be done by the cyclone or the finishing machine, and whether the beater be set loose at low speed or close at high speed, may make a difference of two to five fold or even more on the number of organisms which may be counted. Recent work done at some of the experiment stations upon clarification of milk has shown a similar effect in this product. The mechanical separation of the milk breaks up the clumps of bacteria so that there is in reality a large increase in the count, though no one would contend that its quality or wholesomeness has been injured thereby. A further similarity to what occurs in dairying is shown in pulp and cream allowed to separate by gravity. In both cases the organisms are caught, by the tissue in the one case and by the fat globules in the other, and the count in the upper layer of pulp and in the cream will show a large increase over the original pulp or whole milk, though no actual multiplication has taken place. The cream is not less wholesome because it is separated from the milk, neither does it suddenly become "filthy, putrid, or decomposed" because of the increase in organisms. For a number of years it has been insisted that the number of bacteria in milk was an index of its sanitary character but the more recent work has shown that numbers alone may not bear any close relationship to its sanitary production.

The other factors in manufacture are extremely important in estimating the number of microorganisms present—one is how the cooking has been done and the other is the degree of concentration. The quick cooking at a high temperature, resulting in a reduction to the minimum amount of what is generally called the jellying quality, will bind many organisms to the tissues so that they cannot be counted. Slow prolonged heating will give the reverse effect though it does not change the wholesomeness of the product. The apparent difference between products manufactured by different firms may depend more upon the method of cooking than upon any real difference in material. The addition of a thickener in the making of soups will lower the count. The effect of concentration is always in the direction of increasing the count, though the increase is not in the same ratio as the concentration, but higher during the period while the free water evaporates more readily than when the water is being driven out of the tissue, and if this factor be not taken into consideration wrong deductions may follow. The product of heavily concentrated material will appear at a disadvantage with that of thin material.

These are factors that influence the number of organisms which may be found in a microscopic field irrespective of the method used. They are patent factors which cannot be eliminated in any proper system of examination, neither do they constitute a defense for the substitution of organisms for the food product which it purports to be.

The technique of the method followed in food examination is found in circular No. 68 of the Bureau of Chemistry, and the more recent Bul. 581. Whatever opinion may be held concerning the accuracy of the method itself, as to its adaptability to a product composed of solids and liquids, to the method of preparing the sample, to the use of low powers of magnification, to the lack of differential staining, and to counting of only certain organisms, it is the method which must be used in order to get results approximating those used in official testing. There can be no doubt as to the educational value of this test to certain persons, nor that it has had some effect in bettering manufacturing methods, as will any system of inspection. It is a principle in law that to convict a man of crime, proof must be established beyond reasonable doubt by credible witnesses and, in the case of a food product, this test becomes the witness.

Brief Outline of Literature on the Counting of Organisms.

BESSON, A. Practical bacteriology, microbiology, and serum therapy. P. 856, 1913.

BITTING, A. W. and K. G. Ketchup: Methods of manufacture and microscopic examination. 1915.

BREED, R. S. and BREW, J. D. Counting bacteria by means of the microscope. *Tech. Bull.* 49, New York (Geneva) Exp. Sta., 1916.

CONN, H. W. Agricultural bacteriology. P. 186, 1904.

GOODRICH, G. W. Comparison of the plating and the microscopical methods in the examination of milk. *Jour. Inf. Dis.* 14:512–519, 1914.

HAMMER, B. W. Studies on the clarification of milk. *Bul.* 28, Iowa Exp. Sta., 1916.

HAMMER, B. W. Studies on the numbers of bacteria in milk showing various changes. *Bul.* 29, Iowa Exp. Sta., 1916.

HARDING, H. A., BREED, R. S., STOCKING, W. A., and HASTINGS, E. G. What is meant by quality in milk. *Cir.* 205, Ill. Agr. Exp. Sta., 1917.

HOWARD, B. J. Tomato ketchup under the microscope. *Cir.* 68, Bu. Chem., Dept. Agr., 1911.

HOWARD, B. J. Microscopical studies on tomato products. *Bull.* 581, U. S. Dept. Agr., 1917.

MCINERNEY, J. T. Clarification of milk. *Bul.* 389, New York (Cornell) Exp. Sta., 1917.

MUIR, R. and RITCHIE, J. Manual of bacteriology. P. 138, 1907.

NEWMAN, G. Bacteria. Pp. 178, 186, 1899.

PARK, W. H. and WILLIAMS, A. W. Pathogenic microorganisms. Pp. 599–601, 1914.

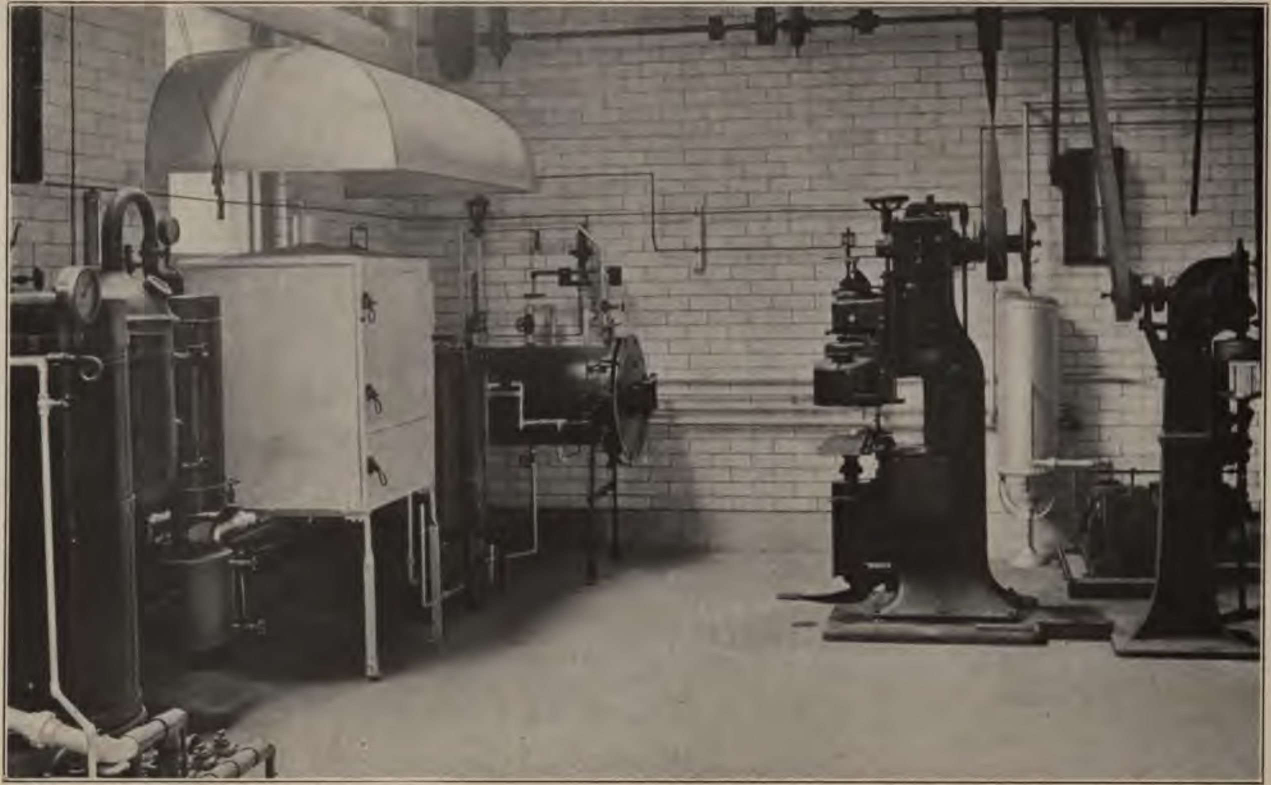
Sternberg, G. M. Manual of bacteriology. Pp. 558, 562, 1892.

Stocking, W. A. Microbiology. Pp. 318, 326, 1912.

Winslow, C. E. A. and Willcomb, G. E. Tests of a method for the direct microscopic enumeration of bacteria. *Jour. Inf. Dis. Sup.*, 1:273–283, 1905.

Weinzirl, John and Newton, E. B. Bacteriological methods for meat analysis. *Am. Jour. Pub. Health*, Vol. 4, 5:408–412, 1914.

Weinzirl, John and Newton, E. B. Bacteriological analyses of hamburger steak with reference to sanitary standards. *Am. Jour. Pub. Health*, Vol. 4, 5:413–417, 1914.



View in the experimental laboratory, showing retorts, sterilizers, and closing machines.

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RESEARCH LABORATORY
W. D. BIGELOW, Director

Bulletin No. 19-L, Revised

Vitamins in Canned Foods

BY
E. F. KOHMAN

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VITAMINS IN CANNED FOODS

INTRODUCTION

Not many years ago it was customary to regard a diet complete and adequate if it contained proteins, carbohydrates, fats, inorganic salts and water in proper proportion and amount. Somewhat later it was learned that proteins are made up of a number of amino acids. Then it was recognized that a complete diet should have such a protein content that all the essential amino acids would be present in sufficient amount. Recent discoveries have added the vitamins as still further requisites of a complete diet.

At present it is generally agreed that there are at least five vitamins. These have been given a variety of names, but the simplest designation is to call them vitamins A, B, C, D, E, F and G. The original vitamin B has been shown to be two closely related substances of different physiological function. It has been suggested that the anti-neuritic fraction be designated F and the anti-pellagric fraction G.

In the role that they play in nutrition the vitamins are very different from the other food constituents mentioned. They supply the body with neither energy nor tissue-building substances. They may be likened to a spark plug. The energy produced in the spark plug does not aid in propelling the engine. Nor is the fuel of any account in running the engine so long as it remains in the form of gasoline. The spark plug, however, ignites it, producing a change whereby it does become useful as a source of energy. By some means, still unknown to us, the vitamins enable the body to utilize the energy-producing and tissue-building components of our foods, which would be useless to us without the vitamins. They play a part in addition to the role of the spark plug in that they have something to do with the construction of the engine; that is, they regulate the assimilation of the tissue-building portions of the diet.

The vitamins are also different in other properties, so far as we know their properties, from other food constituents. They are active in extremely minute quantities. In this respect they bear about the same relation to the rest of our food as the energy produced by the spark plug bears to that generated by the gasoline. Some of the vitamins are less stable under the influence of heat and the action of various chemicals, such as alkalis, than other food components.

Because of these properties of the vitamins, all attempts of chemists to isolate them and determine what manner of substances they really are have met with failure. Practically all of our knowledge of them is based on feeding experiments with several kinds of animals, principally chickens and pigeons among the fowls, and rats, mice, guinea pigs, monkeys, dogs, cats, cattle and hogs among the mammals. At the same time the effect of many different diets for man has been observed in light of the information gained by animal feeding. With few if any exceptions it may be said that all species of animals studied need all the vitamins, but the amount that the different species require varies enormously. Moreover, the requirement of individuals of the same species seems to vary greatly. For this reason any statement of a quantitative nature in regard to vitamins must be regarded as only an approximation.

In the last few years the subject of vitamins has assumed great prominence, both in scientific and popular literature. It appeals to the imagination. The fact that the vitamins are potent in such extremely small quantities and that they have so far completely eluded chemists' attempts to isolate them, surrounds them with a certain amount of mystery. Popular writers have found it a fertile field to exploit. References have been made to vitamins in popular articles and stories on other subjects. Such references are often superficial and incorrect and go to increase popular misinformation. Often their statements are made to apply to all the vitamins, whereas in the source of their information it pertained only to one vitamin. Unfortunately, popular writers are not entirely responsible for the misinformation that obtains on this subject. Recognized authorities have made diametrically opposite statements. This has been the result, in part, of the extreme variability of the methods of experimenting in animal feeding. It has also been the result of a lack of knowledge of the requirements of various species of animals and of the relative amounts of vitamins in different kinds of food products, as well as in the same kinds of products under varying conditions. To some extent it has been attributable to an almost complete lack of knowledge of the chemical nature of the vitamins, because of the inability to isolate them.

As a result, some workers in this field have made statements as to the vitamin content of canned foods that are not in keeping with the results of others and that later evidence has disproved. Sometimes these statements were apparently made without a very definite knowledge as to the treatment of foods in the process of canning and the effect of this treatment on the vitamins.

These contradictions gave popular writers great leeway in their statements. The tendency has been to seize upon the most sensational and expand it to undue proportions. Special interests, not conscientious enough to be compelled to weigh all the evidence, have chosen the statements suited to their particular purpose and have exploited them. More recently, as our knowledge of the vitamins has crystallized, there is an apparent change in the scientific literature. That the vitamins are not affected by heat to the extent formally believed is now commonly accepted. For the information of canners, and to guide them when they meet with these frequent contradictions, a critical survey of the literature has been made in order to arrive at the most accurate conclusion possible as to the status of vitamins in canned foods. These conclusions are briefly stated in the summary on page 7.

Animals in the wild state, when the food supply is plentiful, are safely guided by instinct and appetite to choose a diet adequate for all their needs. With civilized man, this is not always the case. His instinct and appetite often seem to be sophisticated, and many times his free choice is made impossible by social and economic restrictions. A diet even when composed entirely of raw products must, therefore, be chosen with intelligence to insure its adequacy.

A consideration of all the recent experimental evidence convinces one that it is possible to select a diet, entirely of canned foods, which is complete and adequate for long continued nutrition; a diet in which all the known vitamins are represented in sufficient amounts, having such a variety of proteins that no amino acid will be slighted, and supplying all the necessary mineral salts. These more fundamental substances will unavoidably be accompanied by a variety of fats and carbohydrates whose primary function is to supply us with heat and muscular energy.

To make such a diet as palatable, economical and convenient as can be obtained elsewhere, is the problem of the canner. To instruct the public to choose such a diet intelligently is the duty of the nutritional expert, the food chemist and the dietitian. On account of social and economic conditions the foodstuffs in many districts are restricted in variety and it is here that canned foods afford the possibility of extending that variety by making available all of the fundamental requirements at all seasons of the year.

On the other hand canners, as well as all others who have an interest in foods that are subjected to any process of preservation or to storage, should at all times bear in mind that some of the vitamins are not as stable as are the other food constituents. Evidence is accumulating which indicates that even fresh foods, in the raw state, gradually lose a portion of their Vitamin C content even under the best conditions of storage. When these conditions are the best and the time of storage is not unreasonable, the loss is probably of no great significance. Nevertheless "fresh from the fields" is a slogan that every one engaged in handling foods would do well to live up to, and one that the consumer would do well to keep in mind when purchasing raw foods. No one should infer that raw fresh foods should be dispensed with in the normal human dietary. This would be contrary to the universal belief among physiologists and students of nutrition. Those foods which can be eaten raw should always be so eaten as far as possible when they can be obtained in the fresh state, at reasonable cost. When they are out of season, inconvenient or uneconomical, their place can well be taken by canned products. In so far as a direct comparison has been made between canned foods and the same food articles as purchased raw on the market and home cooked, the canned foods have been found in general richer in Vitamin C than the home cooked foods. There is at present no experimental evidence that canned foods are less nutritious than ordinary cooked foods. The practice of cookery is older than history, and no ill results can be traced to its practice. Many foods are only eaten in the cooked form and among them are many which contribute very greatly to our supply of roughage, vitamins and minerals, the food elements in which we are most likely to be short. The foods that are only consumed in a cooked form, chiefly succulent vegetables, should always play an important rôle in the diet.

SUMMARY

It is now fairly generally accepted that there are at least 5 specific vitamins designated as A, B, C, D and E. What was originally designated as Vitamin A, the fat-soluble vitamin, has now proved to be two distinct substances of similar physical properties in many respects, but of different physiological functions. These two vitamins are now designated as A and D. Vitamin B is claimed by some to consist of two substances of similar physical properties, but of different physiological functions, and it has been suggested that the mixture of the two continue to be designated as B and that the two components for which there is now considerable evidence, be designated as F and G.

Vitamin A is found in milk and eggs, largely in their fat, in other animal products, particularly glandular tissues, such as the liver, in animal fats and fish oils, and in vegetables, especially in the green leafy varieties. It has been found to play an important part in the growth of young animals, although it has other, though less clearly defined, functions in the life of both young and old. Its complete absence from the diet results in a specific disease of the eyes known as xerophthalmia, which terminates in death.

Vitamin D, closely associated with Vitamin A, is found in cod liver oil and egg yolk in higher concentration than in any other substance. It has been demonstrated to be present in spinach and alfalfa, but in lower concentration. Its distribution is apparently less wide than is the case with Vitamin A.

Vitamin B is widely distributed in all classes of natural food products, in the germ and bran layer of seeds, in vegetables, fruits and animal products. Its absence in the diet causes the disease known as beriberi in man and polyneuritis in fowls. It is also known as the antineuritic vitamin. It appears to have some function in controlling the appetite. Without it young animals soon cease to grow and finally die. Those who claim that Vitamin B is really two substances maintain that both function in promoting growth in young animals, that one prevents polyneuritis in fowls, while the other prevents pellagra in humans and black tongue in dogs.

Vitamin C occurs abundantly in fruits, succulent vegetables and tubers, and in fresh milk. Its absence in the diet results in scurvy and hence it is called the antiscorbutic vitamin. However, it may be present in the diet in sufficient amount to prevent scurvy and yet in insufficient amount to enable young animals to attain normal growth, or grown animals to be in the best condition.

Vitamin E is known as the antisterility vitamin. Its absence in the diet results in sterility in both males and females, although the specific effect on the reproductive organ of the two sexes is different. The suggestion that Vitamin E plays a similar role in iron assimilation to that of Vitamin D in calcium assimilation is groundless. Some claim there is associated with Vitamin E another substance of vitamin nature which is necessary for normal lactation. These vitamins are rather widely distributed in foods.

The products mentioned above are merely examples of some of the richest sources of vitamins. Many foods contain them in more or less abundance. Likewise the specific diseases mentioned are the results of total or marked deficiencies of the various vitamins. It is to be emphasized that slight deficiencies cause lowered body tone, vitality and resistance to various diseases and infections. Vitamins A, D and E are not appreciably affected by the heat applied in cooking, or in the processing of canned foods. From the experimental evidence now available canned and cooked foods may be said to be practically as rich in Vitamins A and D as are the corresponding raw products. The Vitamin A in fats exposed to air while being heated is gradually destroyed by oxidation. In its natural state, however, as it exists in foods, it has withstood far more severe heat treatment than is ever used in cooking or in processing of canned foods. Vitamin D is equally as stable toward heat, and not so susceptible to oxidation as is Vitamin A. Vitamin E is even more stable than A and D.

Considerable confusion exists as to the effect of heat on Vitamin B, arising from the fact that it is in reality two substances, one of which is stabile and other labile toward heat.

According to several reports, Vitamin B is not appreciably affected by heat in so far as growth in young animals is used as a measure. Judged by its curative action on polyneuritis, mainly as manifested in fowls, this vitamin is apparently destroyed to a more or less extent by heating equivalent to that used in canning and cooking. Others claim that this antineuritic is also essential for growth. It is difficult to make a brief statement more definite.

In the less acid foods, such as animal products and most vegetables, when oxygen is not excluded heating may destroy considerable amounts of Vitamin C. Most of this destructive action takes place at the beginning of the heating process and pasteurizing temperatures are nearly as destructive as the highest temperatures used for processing canned foods. Ordinary cooking may destroy one-half, three-fourths, or even more of the Vitamin C present in the raw product.

The Vitamin C in certain acid foods such as tomatoes, oranges, etc., is not greatly affected by heating for reasonable periods at boiling temperatures. Just what is the role of the acidity is uncertain. Neutralizing the acid in part tends to make the Vitamin C less stable, but acidifying the less acid foods has not been found to make the Vitamin C more stable.

There is now considerable evidence that commercially canned foods are richer in Vitamin C than the same foodstuffs home-cooked. Certain conditions in the sterilizing process that canned foods receive, but which do not obtain in home-cooking, are such that they tend to preserve this vitamin. Also, in some products purchased raw on the market, the time which elapses between harvesting and cooking is considerably greater than that occurring in canned foods and there is evidence that raw foods lose Vitamin C during storage.

When the first edition of this bulletin was written in 1922, with the exception of milk and tomatoes there were practically no data pertaining to the vitamin content of commercially canned foods. There was a large number of experiments reported in the literature dealing with the stability of the vitamins under a variety of heat treatments. Based on these data, the conclusion seemed logical that heat in itself within the ranges used in commercial canning had no great destructive action on the vitamins; that Vitamins A, D, E and also B as measured by its growth promoting effect on rats were probably very little affected by canning; and that when Vitamin C was affected, it was largely because of some other factor than heat, such as oxidation, and the heat merely accelerated the oxidation effect. This revision of this bulletin is in the main identical with the previous revision in 1924 with the exception of the enlargement of this summary to include the recent work directly pertaining to canned foods. The tables remain unchanged.

There is now a considerable number of reported experiments dealing directly with the vitamin content of commercially canned foods which, in general bear out the above conclusions. Some of the earliest work dealt with evaporated* and condensed* milk. Rosenau and also McCollum[82] arrived at the conclusion that evaporated milk had practically its original potency in Vitamins A and B. Daniels and Laughlin[109] found no evidence that either condensed or evaporated milk had lost any Vitamin B, but that the condition of the calcium and phosphorous was changed probably by precipitation, which caused it to settle out. Unless this was again brought into suspension as by means of starch paste, the results might have been interpreted as meaning that Vitamin B was lacking due to inferior growth as result of insufficient calcium and phosphorous. More recently Hartwell[259] reports that evaporated milks, of which he tested two samples, are lower in Vitamin B content than fresh or dried milk, but gives no quantitative results.

Dutcher, Francis and Combs[260] experimented with milk evaporated under vacuum and also while being aerated, and reported that rats receiving the equivalent of 6 cc. per day of raw and evaporated milk gave some evidence that Vitamin B was affected by the heat and aeration, but when 8, 10 or 12 cc. were fed, there was no difference between the raw and evaporated apparent. In other words, the maximum amount of B that could have been lost was 25%.

As regards Vitamin C in milk, Hart, Steenbock and Smith[142] state that 45 cc. evaporated milk daily per guinea pig gave no evidence of Vitamin C. Alonzo Taylor[143] found that 8 oz. of condensed milk per day cured and prevented scurvy among children in the war zone during the World War. Hess[144] states that condensed milk may retain much of its Vitamin C, and that condensed milk may cure infantile scurvy. Hume[145] experimenting with monkeys found no evidence that the commercial canning of condensed milk caused a loss of Vitamin C.

Commercially canned tomatoes have likewise been tested by a number of different individuals. Osborne and Mendel[83, 112] dried canned tomatoes for the purpose of testing Vitamins A and B. Even after this additional process of drying, they report the dry material to be equivalent to, or more potent than butter fat in Vitamin A and a good source of Vitamin B. One tenth of one gram as a source of A, and from 1 to 1.5 grams as a source of B are adequate for normal growth in rats. Hess and Unger[44] found that in feeding commercially canned tomatoes stored one year to guinea pigs, 1.5 cc. was not protective, 3 cc. usually was protective and that 5 cc. always was protective. Givens and McCluggage[152] found that 3 cc. of commercially canned tomatoes was

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***Evaporated milk is sterilized by heat. Condensed milk is preserved by its sugar content.**

an adequate antiscorbutic for guinea pigs. LaMer[261] compared one lot of commercially canned tomatoes with raw tomatoes grown in his own garden and found the canned equivalent, or slightly superior in Vitamin C content to the raw. He reports 3 cc. as the protective dose of both raw and canned. With the exception of Delf[243] 3 cc. is the smallest amount of raw tomatoes reported by any one as adequate for guinea pigs. Delf, an English worker, states that 2 cc. was the protective dose and that after canning, 7.5 cc. was necessary, and after 3¾ years, 8.5 cc. were required. This high loss of Vitamin C in canning is so at variance with the reports of American workers that one is led to look to the raw product which was used, or the method of canning which was employed for an explanation of the wide difference. Tomatoes in England are grown under vastly different conditions than in the United States, and the canning method used is not the commercial method here employed. In some unpublished work just being completed, we have tested one lot of canned whole tomatoes and found 2 cc. to be almost protective against scurvy, and that 3 cc. resulted in full normal growth, kept the animals in excellent condition and always insured against scurvy. Since these tests must run over a period of approximately 90 days, an exact comparison of tomatoes from one lot, raw and canned, is not possible, because raw tomatoes cannot be stored for so long a time.

In connection with Delf's work on tomatoes, her work with oranges is of interest. She found that when oranges were canned[186] by using a process of 20 to 30 minutes, gradually bringing the temperature up from 176° to 212°, so that the temperature was at 212° not more than 5 minutes, there was no loss of Vitamin C. An amount of the canned orange which represented 1.5 cc. of orange as it went into the can was equivalent to 1.5 cc. of raw orange. Again testing this canned orange 4 years later[262] she found that not more than 10% of the Vitamin C was lost during this storage period. In this conneciton it may be stated that it is questionable whether Vitamin C can be assayed any more accurately than within a range of 10%, and that, therefore, this loss which she reports on storage may in part be due to experimental error.

Miller[101] canned diced carrots processing them 45 minutes at 239° F., and states that there is no evidence of loss of Vitamin B, although varying amounts to find the minimum protective dose were not fed.

Campbell and Chick[146] canned cabbage by processing 1½ hours at 212° and reported a loss of 70% of the Vitamin C, but did not feed the liquor in the can which constituted 39% of the contents.

Morgan and Stephenson[208] canned artichoke by processing 1 hour at 250°, and also 1 hour at 212° on three successive days. There was little evidence of any Vitamin A being lost, but the author states that approximately 50% of the Vitamin B was lost. This is partly an estimation because the amounts fed were not varied sufficiently to definitely establish the border line.

Eddy and Kohman[249] canned cabbage varying the process as follows:

Time of Process in Minutes	*Temperature of Process*		
15		240°	
30	212°	240°	260°
45		240°	
60		240°	

These various lots were fed in several different amounts so as to find the minimum protective dose as an antiscorbutic for guinea pigs. This was found to be an amount representing 4 grams of cabbage. The minimum protective dose of cabbage cooked in an open kettle for 15-20 minutes was 20 grams.

The same authors in a similar experiment with apples[194] found that due to the high oxygen content, apples lost all their Vitamin C in baking, in making apple sauce and in canning by the ordinary procedure. They also found that in cold storage apples lost about one-half of their Vitamin C from October to March or April, a period of storage normal for the variety of apples employed. Effect of the oxygen in canning was eliminated by allowing the respiratory process of the apples to deplete their own content of oxygen by a described method. The apples could then be canned and there was no apparent loss of Vitamin C whether the process was 10 minutes, which is normal for the size of cans used, or 30 minutes, i. e., three times the normal period. Eight months after canning, these apples were still equivalent to the raw apples as tested at the time of canning. This experiment demonstrates in a unique way the effects of oxygen in the destruction of Vitamin C, and is evidence of the negligible effect of heat in the absence of oxygen.

In a somewhat similar experiment with peaches[263] it was further found that peaches in canning lose very little, if any, Vitamin C if the effect of the oxygen is eliminated, but that the oxygen content in peaches is relatively small and its effect negligible as compared with the oxygen in apples. In this respect the results with peaches resemble the results obtained with tomatoes, oranges, and pineapples.

Miller[264] studied the vitamin content of pineapples before and after canning. In case of the canned pineapple, only the slices were fed in the study pertaining to Vitamins A and B. Five and ten gram amounts were fed of both the canned and uncanned material. Five grams proved to be almost sufficient for the Vitamin A or Vitamin B to produce normal growth, and the growth curves for the canned and uncanned were very similar. In some of the animals, 10 grams gave somewhat better growth, whereas in other animals it appeared to make little difference. Although it is possible that there was some destruction of either Vitamin A or B in the canning process, it would be difficult to definitely draw that conclusion from the growth curves of the animals. In the experiments pertaining to Vitamin C, 5 grams of the uncanned and canned pineapple equivalent to 7.7 grams of pineapple as it went into the can were found to be approximately equivalent in Vitamin C content. On this basis, the canned pineapple is approximately two-thirds as rich in Vitamin C as the uncanned.

Eddy, Kohman and Carlsson have also made a comprehensive study of spinach[211] and peas[265]. In both the canned spinach and canned peas, the time of the process was varied in one lot of spinach and also of peas, making it double that of the commercial process normally used. Although there was some destruction of Vitamin C in both spinach and peas, this doubling of the process did not noticeably increase this destruction, showing that the destruction must have occurred early in the canning process. In the case of the spinach, 0.25 to 0.5 gram of raw spinach was found to be the equivalent of 2 grams of canned spinach, or 10 grams of home cooked spinach as a source of Vitamin C. Neither the canning nor the home cooking process affected the Vitamin A, 0.026 grams of either being the equivalent of 0.020 gram of butter fat. Approximately 0.100 gram of peas and 0.026 gram of spinach respectively was the equivalent of 0.020 gram of butter fat. It should be borne in mind that peas contain over 70 per cent, and spinach over 90 per cent moisture. Their vitamin content on a dry basis would therefore be much higher. From 2 to 3 grams of canned peas were equivalent to 6 cc. of milk as a source of Vitamin B, while 2 grams of raw peas were the equivalent of 5 grams of home cooked or 3 grams of canned peas as a source of Vitamin C. These three amounts daily were the minimum required as antiscorbutic for guinea pigs. From these results with canned spinach and canned peas, it is evident that they are both excellent sources of Vitamins A and C, and that peas are also an excellent source of Vitamin B, while spinach is low in its content of Vitamin B even in the raw state. The canning of strawberries[269] does not affect their vitamin A, B, or C content, nor does a subsequent storage period of 14 to 18 months.

It so happens that some of the foods used for canning in largest quantity are particularly rich in vitamins. This makes possible the following interesting comparisons. Canned tomatoes are richer in Vitamins A and B than orange juice and somewhat lower in Vitamin C content than orange juice. Canned peas are very much richer in Vitamins A and B than orange juice but have somewhat less Vitamin C content. These two foods are canned in the largest amount with the possible exception of corn. Figures on the vitamin content of corn have not yet been obtained. Spinach is the richest source of Vitamin A with the exception of cod liver oil, richer than even butter fat and its Vitamin A content is not lowered by the canning process.

Raw spinach is so rich in Vitamin C that even with considerable loss in canning, the canned spinach still approximates oranges and tomatoes in its Vitamin C content. The vitamin content of canned oranges, tomatoes and spinach has been tested three to four years after canning and the maximum loss during this storage period in any case was not more than 10 per cent. Canned cabbage, peas and spinach were shown to be richer in Vitamin C than cabbage, peas and spinach, respectively, purchased on the market and "home cooked" by the customary methods. Canned peas and spinach are richer in Vitamins A and C than milk; canned peas are also richer in B than milk, and canned cabbage richer in C than milk. This is true in spite of the fact that these vegetables are not among the acid foods, such as fruits, and indicates that the popular notion, that acidity and the stability of vitamins always go hand in hand, is not justified. This statement is borne out by the fact that the acidifying of non-acid foods does not increase the stability of their vitamins in cooking. The data with reference to canned foods is sufficient to justify the statement that canned foods may be a very valuable asset in supplying the various vitamins.

In acid products, such as tomatoes and fruits with little oxygen in them, there is only a negligible destruction of Vitamin C by ordinary cooking or in the canning process. The stability of Vitamin C towards heat depends to a great extent on the presence or absence of air. In processing canned foods, air is excluded as far as possible. Therefore one would expect less destruction of Vitamin C in processing canned foods than in cooking for the same time and temperature in the presence of air.

Apples are not rich in Vitamin C. This is practically all destroyed by the oxygen within the apples in baking or in cooking, as in the preparation of apple-sauce, or by canning without provision to eliminate oxygen. A method is now in common practice by which the oxygen is removed in a very simple manner and the vitamin preserved in canning.

It has been shown that raw products such as carrots, fresh milk, orange juice, and apples lose their Vitamin C markedly on storage even at low temperatures. We do not know to what extent this is true of other raw products. Vitamin C, the least stable of the vitamins, has been held for three years in canned tomatoes, oranges, and canned spinach with no depreciation that can be definitely measured. This is a much longer period than is possible by any other known method. Present experimental evidence on the subject leads one to believe that the amount of Vitamin C in canned products does not decrease on storage, although it is true that only rather highly acid products have been examined in this connection. If this is proved always to be the case, the canning of foods is an ideal means of keeping the vitamins through long periods of storage.

Many foods are not eaten in the raw state and among such are some of our richest sources of the vitamins. Moreover, in the case of certain foods which are eaten both raw and cooked, such as cabbage, carrots and some fruits, considerably larger portions are consumed in the cooked form than in the raw state. In general, cooked foods are consumed in greater bulk than raw, and they thus become the source of a large proportion of our vitamins. A greater consumption of succulent foods is generally agreed to be desirable. Canning makes these available to a much greater extent than would be otherwise possible.

NATURE OF VITAMINS

It was recognized many years ago that foods played a more complex role than to supply us with energy and tissue-building materials. In 1757 James Lind[3] stated that scurvy resulted from the absence of fresh foods, especially vegetables, in the diet. More definite knowledge than this accumulated only when unsuccessful attempts were made to feed animals on so-called synthetic, or chemically pure, products. These attempts resulted in diseases which had a close resemblance to certain human diseases, whose origin was therefore much clarified. Thus Eijkman[4] reported the discovery that the outer layers of rice contain a curative substance for polyneuritis in fowls and beriberi in man. At about the same time, in 1895, Smith[5] reported that guinea pigs died of a hemorrhagic disease when fed on an exclusive diet of cereals without succulent vegetables. In 1907 Holst and Frölich[6] directed attention to the similarity between this malady and human scurvy. They also pointed out a little later that ship beriberi, common on sailboats taking long voyages, had a similar origin.

These fundamental discoveries led to the present view that there are a considerable number of vitamins which are essential in order that foods may afford complete nutrition. The vitamins have been designated by various names, such as "accessory factors of the diet," "auximones," "nutramines" and "vitamins." McCollum, after the existence of the first two was established, designated them as fat-soluble A and water-soluble B, because the former was first found in butter-fat and egg-yolk fat and was soluble in fats, whereas the latter was more soluble in water. But it is now stated[189] that Vitamin A is about one-thirtieth as soluble in water as in fat and as the fat in milk is roughly one-thirtieth of the whole milk, this vitamin is about equally distributed between the fat and non-fat portions. The most general usage now designates this vitamin as Vitamin A. Moreover, the water-soluble vitamin is now known to be somewhat soluble in fats and it is more commonly called Vitamin B.

The third vitamin to be discovered, whose absence in the diet results in scurvy, is known as Vitamin C or the antiscorbutic vitamin. This also is a water-soluble vitamin.

It was next shown that closely associated with Vitamin A is another vitamin, and this was designated Vitamin D. It is abundant in cod liver oil and is capable of preventing or curing rickets and hence is called also the antirachitic vitamin.

It is now known that exposure of growing animals to ultra violet light, i. e., light of such short wave length as to be invisible to the eye, but which affects photographic plates, or even to direct sunlight for sufficient time because sunlight contains some ultra violet rays, accomplishes the same thing as including cod liver oil in the diet. In either case rickets is prevented and normal bone formation is accomplished. Moreover, the same may be accomplished by exposing the food eaten, or a portion of it containing an appreciable amount of fat-like material. In this way any vegetable or animal oil may be given the properties of cod liver oil. Furthermore, chemically pure ergosterol, which is normally present in small quantities in animal and vegetable oils, may be given similar antirachitic properties. It is to be inferred that it is the ergosterol in the skin that is so affected by exposure to ultra violet or sunlight. More recently it has been shown that unless animals have in their diet a hitherto unrecognized vitamin-like substance originally designated as Vitamin X but now as Vitamin E, sterility results both in males and females. Closely associated with this seems to be another substance which is necessary for normal lactation.

When the existence of these food constituents was once established, many investigators attempted to solve the alluring problem of determining the relative amounts in man's foods, to isolate them in pure form and to devise accurate chemical methods for their analysis.

This soon led to the realization that vitamins were not always stable to the chemical reactions and conditions to which the foods were subjected. This opened the second problem of determining their stability to the various cooking and preserving processes.

In many instances the investigator did not realize all the conditions which affected his problem. For example, in studying conditions which might destroy Vitamin C in milk it was not realized for some time that the vitamin content in the fresh milk might vary enormously, depending on the cow's food. Or, again, destruction during heating was ascribed to the effect of heat when as a matter of fact the destruction was in reality due to oxidation which was not excluded.

Thus a great many difficulties have been encountered, both in attempts to isolate the vitamins and to determine their stability in man's foods.

These difficulties were formerly not always realized, and therefore were passed over. As a consequence, many of the results thus obtained were far from accurate and often misleading. Any data based on the variability found in the individual animals used for feeding tests can only be approximate unless a sufficient number is used. When we translate results, arrived at by feeding various species of animals, into terms of man's requirement, it is obvious that they can only be approximate. In the case of specific diseases in man, such as scurvy, and to a less extent beriberi, our knowledge is somewhat more definite. These, however, are diseases resulting when there is almost a complete absence in the diet of the vitamins concerned, a condition which is very uncommon under practical conditions.

Diseases resulting from an almost complete absence of vitamins is perhaps not the most important consideration. Hess[2] says: "Clear-cut disorders should not be regarded as the most common or important result of food deficiencies. It should be realized that the lack of these essential food factors generally does not bring about typical pathological states, but obscure alterations of nutrition, ill-defined functional disabilities, which cannot be characterized or even recognized as disease. It is such incomplete larval forms of the deficiency disorders to which physicians will have to address themselves." McCarrison[174] points out that a low vitamin content in the diet renders the body more liable to infection. He calls attention, however, to the fact that these essential dietary constituents are in no wise different in this respect from the others, such as complete proteins, inorganic elements, etc. Views such as these are expressed by many in the literature on the subject. From these standpoints we know very little as to man's quantitative need of vitamins. But we do know that a reasonably wide variety of good, wholesome, nutritious food in ample quantities is the first principle of nutrition. This is as necessary for an adequate supply of proteins and mineral salts as for the vitamins. It is the only practical means of attaining ideal nutrition.

The vitamins are as yet largely a mystery to chemists. Their composition is not known and, ergosterol excepted, they have not been isolated. Our knowledge of them is based on their effect in the diet of animals. Individual idiosyncracy in the matter of food is as marked in other animals as in man. Therefore in vitamin studies many animals must be fed to obtain reliable results. This often is prohibitive from the standpoint of time and money. Even greater than the variations of individuals are the variations of different species of animals.

The same kind of food may vary greatly from time to time in its vitamin content. Carrots have been considered as good antiscorbutic food as a result of feeding guinea pigs. But Hess and Unger[44] found old carrots much inferior to young, freshly harvested carrots. Oranges, on the other hand, have been found to retain Vitamin C after three months of cold storage. Partially ripened tomatoes have been found inferior to the well ripened and variations of 100 per cent or over in the same kind of food but of different origin are not uncommon. Seeds and tubers were at first considered to be poorly supplied with Vitamin A, but Steenbock has pointed out that carrots and sweet potatoes, i. e., in general the colored tubers, are well supplied. Among the seeds, millet and the more deeply colored varieties of peas have considerable Vitamin A. Yellow corn is rich in it while the white variety is practically devoid of it. Animal fats are found to vary, depending on the feed of the animals. The amount of all the vitamins in milk may vary several hundred per cent as a result of the variation in the feed. This is discussed in a separate section. Eggs and other animal products are believed to vary in a similar manner.

Destruction of vitamins has been ascribed to certain treatments, the results of which are now known to have been wrongly interpreted. The heat of pasteurization has been said to destroy Vitamin C of milk. It is now known that the destruction is largely if not wholly due to oxidation caused by the oxygen of the air. If the milk is heated in the absence of air Vitamin C is retained to a much greater extent. It is lost to a large extent even by storing the milk on ice for 48 hours whether previously heated or not. A similar loss is noted for orange juice on page 57 (also Expts. 452 and 453.* Such periods of storage have not been uncommon even in experiments on vitamins, and no allowance was made for their effect on the results. In order to determine the amount of Vitamins A and B in many products, such as animal tissues and fresh vegetables, they were first reduced to a dry state in order to have a uniform product throughout a feeding experiment. The effect of the drying, if there was any, on the vitamin content was thus not taken into account. Milk has been dried and autoclaved for use in scorbutic diets with the scarcely justifiable assumption that all the antiscorbutic vitamin was destroyed.

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* For experiments see tables beginning on page 61.

A change in the vitamins in the animal's diet may necessitate a material change in the remainder of the diet. A resulting change in palatability may cause a difference in the amount of food eaten. In some cases this has been neglected, and in all cases it is a disturbing factor.

If an animal is receiving twice as much of a certain vitamin as it requires, destruction of one-half of it may occur before the animal shows any signs of it. Even within recent date, poorly regulated experiments of this kind were reported by workers who had data available by which they could have regulated their experiments more closely.

Experiments to determine the stability of vitamins have frequently been conducted on juices and extracts, but there is good reason to believe that their stability, under these conditions, is not the same as in the natural food product.

When foods are cooked, it is a rational assumption that the water-soluble vitamins will distribute themselves between the water and the food product. The amount that goes into the water will depend upon the amount of water and the time it is in contact with the food. In some recorded experiments the cooking water was disregarded. Delf[183] has recently given a striking illustration of this. She found 17 grams of liquor from germinated cow peas gave better growth in guinea pigs than a like amount of the peas themselves.

From the above discussion it is obvious that our knowledge of man's normal requirements of vitamins is not based on very definite or conclusive evidence. Even in the case of experimental animals, one experiment, or the experiments of one worker, cannot be considered a definite answer to a question pertaining to vitamins. It must be considered in the light of other experiments, and when we attempt to translate the results obtained by animal feeding into terms of human requirement, there is great danger of error. Consider for example the following illustration.

To supply a guinea pig with sufficient Vitamin C to protect it against scurvy 1.5 cc. of lemon juice is almost universally agreed to be sufficient. In some cases 1.0 cc. has sufficed. We know of no case when more than 1.5 cc. was necessary. There is less evidence to show the amount of sprouted seeds that will take the place of this amount of lemon juice for the above purpose but Chick and Hume[23] have recorded success with 5 grams of germinated pulses and Chick and Delf[148] have found 10 grams of germinated peas and lentils (5 grams weighed dry) necessary as against 30 to 40 grams of the unsprouted to protect a guinea pig against scurvy. It would seem, therefore, a conservative estimate to regard lemon juice as two or three times as rich in the antiscorbutic vitamin as sprouted seeds. This was not confirmed, however, by the following experiment with about sixty Serbian soldiers suffering from scurvy.

Wiltshire[182] divided these patients alternately as they came into a London war hospital between two wards. In all he finally had thirty in one ward and twenty-seven in the other. To each of the first group he gave four ounces of fresh lemon juice daily and to each of the second group he gave daily the product resulting from four ounces of haricot beans weighed dry, soaked 24 hours, germinated 48 hours at 140 to 158 degrees F. and then cooked 10 minutes. Wiltshire states that in the beginning the patients receiving the sprouted beans were more severely rather than less severely afflicted than the other group. Yet in four weeks 70 per cent of those receiving the sprouted beans had recovered as against 53 per cent of those receiving the lemon juice. A better comparison of the efficiency of the two remedies, Wiltshire states, is the time required for the gums to return to normal conditions, which averaged 3.1 weeks for the patients receiving the beans and 3.4 weeks for those receiving the lemon juice. It should be borne in mind that these beans are a non-acid product, therein resembling the vegetables in which the antiscorbutic vitamin is said to be least stable to boiling. Yet they were very efficient antiscorbutics, more so than lemon juice, after being boiled ten minutes. Chick and Delf[148] found boiling fifteen minutes destroyed 75 per cent of the antiscorbutic value of germinated peas and lentils.

Again, Chick and Rhodes[147] found 17 to 20 grams of boiled potatoes necessary to be the equivalent of 1.5 to 3.0 grams of orange juice as an antiscorbutic. Yet, as cited later, a shortage in the potato crop has several times been given as the cause of scurvy epidemics. In the face of experiences like these, statements belittling cooked foods as sources of vitamins are of questionable propriety.

VITAMIN A

The first food product in which Vitamin A was found was the fat of milk and eggs, which have subsequently proved to be important sources among man's foods. They, however, are indirect rather than primary sources. It is generally believed that animals cannot produce or synthesize the vitamins, but that this is a function of the plant kingdom alone. The production of Vitamin A is said by some to be closely associated with the activities of the chlorophyl or green-coloring-matter of plants. Various forms of algae (Fucus, Ulva, Cladophorous, Polysiphonia and Entromorpha), as well as diatomes (Nitzshia), have all been found to synthesize Vitamin A. Although the larger fish do not depend on these as their food supply, they feed on small marine creatures who do and thus ultimately get their supply of vitamins from these marine plants.[192]

When seeds are sprouted in the absence of light, according to Coward & Drummond,[178] Vitamin A is not produced, but as soon as the sprouts come to light and the tips begin to turn green, Vitamin A is formed. Wilson,[179] on the other hand, found that Vitamin A was formed when wheat was sprouted in the dark, though he admits the production is probably more rapid in the light. Coward[193] claims, subsequently to have shown wherein Wilson's experiments are at fault and seems definitely to have shown that light is necessary for Vitamin A formation, that oxygen or carbon dioxide are not necessary and that chlorophyl activity is not involved. Chloroform in the atmosphere prevents its synthesis. In a very recent report Coward [266] shows, however, that small amounts of A may form in shoots a few inches high when seeds of white and yellow corn and of wheat are sprouted in complete darkness.

The origin of this vitamin in milk and eggs is thus the green grass and hay used as feed in their production. The animal consumes the plant tissues, converts more or less of them into fat, and this fat acts as a solvent or carrier for the vitamin. It so happens that the cow's and hen's food usually contains a considerable proportion of green plant tissue, when the two animals are to produce milk and eggs, respectively. If they are to be fattened for market, this type of food is replaced by a more concentrated ration of grains and their body fat therefore contains relatively less Vitamin A. An important direct source of this vitamin for man is the green plant tissues he consumes, such as spinach, chard, cabbage and lettuce, particularly the green varieties.

Although the production of Vitamin A is probably associated closely with the chlorophyl activities, it may be stored in parts of the plant containing no chlorophyl. Thus the seeds may be more or less supplied with it and, in general, the seeds with color contain most. For example, yellow corn contains considerable, whereas in white corn there is very little. Millet, linseed, soy beans, and haricot beans are other seeds with considerable amounts, although probably no seeds are entirely without it. Certain vegetables, as carrots, sweet potatoes, parsnips and mangels, are good sources of this vitamin, and the tomato is as rich in this respect as butter-fat itself based on the dry substance, whereas spinach is richer.

There is a tendency for Vitamin A to concentrate or to be stored in the vital organs of animals. The fact that beasts of prey often consume these organs of their victims before the other parts has been explained on this basis. It has been found that the kidney, liver, heart, etc., contain it in considerable amounts. This has been experimentally established in the case of these organs in the pig. Frequently the fats rendered from the vital organs are extremely rich. Cod liver oil has it in more concentrated form than any other known substance, and it is variously rated in this connection as being from 1 to 250 times as potent as milk-fat. Other fish oils, such as whale, herring and salmon oils, are also known to contain Vitamin A. This ability to store vitamins is said by some to enable animals to do without them for a considerable period and draw on their reserve supply.

It is evident from the foregoing that by partaking of a variety of foods, man stands little chance of missing this vitamin in his diet. But there are a number of instances where serious results have followed a too low supply in the human diet. Too small an intake is held responsible for various eye troubles. There are on record a number of instances where an epidemic of eye disorders in times of food shortage was remedied by the inclusion of cod liver oil, chicken liver or butter-fat in the diet. A condition termed "night blindness" was reported in northern lumber-camps, among Austrian prisoners of war in Russia during the late war, among Russian peasants in peace times, among Japanese coolies in various districts of Japan, and among Japanese soldiers. This is ascribed to the fact that insufficient Vitamin A was included in the diet. In Japan children have been found to suffer from eye diseases which could be cured by chicken livers, eel fat, cod liver oil and other fish oils. In Denmark similar diseases have been traced to parallel excessive exporting of butter. As a result, butter was rationed in 1918 and 1919 and eaten by all with a great falling off of the eye trouble.

In young rats the lack of the potent substance found in milk-fat will first result in a failure to grow and therefore it has been designated as the "growth-promoting" vitamin. But growth will eventually cease whenever any necessary item is not included in the diet. If proteins or certain amino acids are lacking, growth will be sure to cease for lack of tissue-building substances. The same is true if calcium or other necessary mineral constituent is lacking. One food component is as worthy of the designation "growth-promoting" as another, although they may function differently. It is very common, for example[104] in feeding guinea pigs on rations with sufficient Vitamin C to maintain them free from scurvy, but insufficient to give normal growth.

A later consequence to young and old rats of lack of Vitamin A is an inflamed condition of the eyes, called by various investigators an ophthalmia, conjunctivities, xerophthalmia or a keratomalacia. Dermal malnutrition may occur as evidenced by thin bushy fur.

VITAMIN D

Rickets is a disease which has been associated more or less with insufficient Vitamin A. Dalyell[8] recently found that 50 per cent of breast-fed infants in Vienna were diagnosed as suffering from rickets at 5 months of age and 100 per cent at 9 months. Hess[2] says further that "Rickets is the most common nutritional disease occurring among the children of the temperate zone, fully three-fourths of the infants in the great cities, such as New York, showing rachitic signs in some degree." He has calculated that by giving a teaspoonful of cod liver oil three times daily to infant patients New York could in a short time be freed from rickets at a cost of $100,000.

Recent experiments have thrown much light on the nature and cause of rickets although the matter is still too unsettled to bring out all phases of these developments in a short discussion. Sherman and Pappenheimer[9] and also McCollum, Simmons, Shipley and Park[10] have produced rickets in rats on a diet characterized by being low in phosphorus and the fat-soluble vitamin as it occurs in cod liver oil. The latter have, moreover, produced skeletal malnutrition other than rickets on diets characterized by having a low calcium content and lacking the fat-soluble vitamin in cod liver oil, but which were adequate in all other respects. If one or two per cent of cod liver oil was included in these low phosphorus or low calcium diets normal development of the bones took place. The cod liver oil of course supplied neither calcium nor phosphorus but stimulated metabolism so that more efficient use was made of the small amounts of these elements present in the diet. If the phosphorus and calcium were both made adequate, and there were no other adverse conditions, the cod liver oil could apparently be omitted. But if both calcium and phosphorus were low the cod liver oil did not prevent malnutrition of the bones although the condition that developed was not rickets.

Butter fat did not take the place of cod liver oil in supplementing the low calcium or low phosphorus diets mentioned above, even if twenty per cent was included in the diet. In this connection it is of interest to note that Hart, Steenbock and Hoppert[84] showed that there is something in green oats in contrast with dry oats straw which increases the amount of calcium assimilated. Cod liver oil acted in a similar way, whereas orange juice or raw cabbage had no effect, showing that it was not Vitamin C in the green oats which was the active principle.

It has been shown by Hess and associates[11] that rickets in infants can be cured by exposure to sunlight, and by Hess, Unger and Pappenheimer[12] that rickets in rats on a low phosphorus diet like that used by Sherman and Pappenheimer can be prevented in a similar manner. Moreover, McCollum and his co-workers[10b] have shown that exposure to direct sunlight will prevent rickets in rats on low phosphorus diets in a similar manner to cod liver oil and likewise[10a] that sunlight will stimulate bone development in low calcium diets as does cod liver oil.

It thus appears that some constituent of cod liver oil and the rays of the sun act alike in stimulating the development of the bones of the skeleton. This constituent is not the fat-soluable Vitamin A in butter-fat, although cod liver oil is also very rich in it. To find the origin of this bone-nourishing substance in cod liver oil and further determine its occurrence in other products is an interesting problem for future investigation. American workers are fairly generally accepting the hypothesis as fact, that the antirachitic factor in cod liver oil is different from the growth promoting factor, or Vitamin A, and it is commonly designated as Vitamin D. Some of the reasons for their views are given in Expts. 36 to 41, inclusive, from which it appears that the resistance of the antirachitic factor toward various treatments is distinctly different than is the case in Vitamin A proper. On the complicated etiology of rickets all are agreed. There are unquestionably at least five influential factors involved, i. e., exercise, sunlight, calcium, phosphorus and the antirachitic vitamin.

One of the most striking developments in connection with vitamins is that recently consummated by Steenbock and Black.[195] Goldblatt and Soames[196] had previously shown that if rats on a diet deficient in antirachitic vitamin are irradiated by the rays of a quartz mercury vapor lamp, and their growth thus stimulated and their livers subsequently fed to non-irradiated rats, the growth of the latter is stimulated. If livers from non-irradiated rats are fed, no growth stimulation results.

It is now known that any food containing fat-like or oily matter may be given the antirachitic properties of cod liver oil by exposure to the ultra violet rays of a quartz mercury vapor lamp, the specific effect probably being on the ergosterol of animal and vegetable products, since ergosterol in chemically pure form may be given antirachitic properties also.

There are at least two viewpoints that must be considered in explanation of these phenomena. There is the possibility on the one hand that the antirachitic factor in cod liver oil and other foods is active by virtue of giving off radiant energy in the form of ultra violet waves. In this connection Kugelmass and McQuarrie[197] have shown that, under certain conditions, cod liver oil is able to affect a photographic plate. On the other hand, it may be that the substance involved exists in an active and inactive form and that ultraviolet rays are capable of bringing about a molecular rearrangement in the substance involved, converting the inactive into the active form both in living animals and in food materials. The fact that Kugelmass and McQuarrie[197] found only oxidized cod liver oil would affect a photographic plate, in view of the fact that oxidation tends to destroy the antirachitic factor, is not in harmony with the idea that this factor is antirachitic by virtue of giving off radiant energy. Kugelmass and McQuarrie also found oxidized cod liver oil gives off oxygen when exposed to ultra violet rays.

It has repeatedly been reported that Vitamins A, B and C in cow's milk occur in proportion as they are found in the food of the cow. Recently Luce[198] has reported that both Vitamin A and the antirachitic factor are increased in cow's milk by green fresh feed as contrasted with dry feed; also by giving the cow access to sunlight, as contrasted with keeping her in a dark stall, her food being the same in both cases.

Recently Hughes, Fitch, Cave and Riddell[267] reported evidence, however, that the Vitamin C content of a cow's ration has little, if any, influence on the Vitamin C content of its milk, and believe that the dairy cow is able to synthesize Vitamin C.

VITAMIN B

When Eykman[4] found that the outer layers of rice, i.e., rice polishings, would cure beriberi in man and polyneuritis in birds, he opened the extremely fruitful field of nutritional investigations which has led to the discovery of the Vitamins. At the same time, he indicated one of the important sources of Vitamin B. Subsequent investigation has shown the bran layer and the germs of seeds to be rich in Vitamin B. But this vitamin is widely distributed in other products. Practically all the vegetables, both leaves and tubers, most of the fruits and nuts, and among the animal feeds, the various hays, are well-supplied with it. With a varied diet it would seem almost impossible not to partake of this factor in sufficient quantity.

Just where and how Vitamin B is formed in nature is not definitely settled. It has been suggested that it is a product of soil bacteria and is utilized from the soil by the plants. Its storage in the germs of seeds supplies the young plant or sprout until roots are sent out into the soil to secure its food supply there. It has been found by Fürst[180] that the sprouting of seeds is accompanied by a decrease in Vitamin B, and by Grijns[181] that the antineuritic factor decreases. Santos,[199] on the other hand, reports that the sprouting of mango is accompanied by an increase in Vitamin B. MacDonald and McCollum[18] have demonstrated that yeast can either grow without Vitamin B or synthesize its own supply. Fulmer, Nelson and Sherwood[14] have proved that yeast produces Vitamin B from chemically pure salts and cane sugar. Similar results, although less definite and conclusive, have been obtained by various investigators from some bacteria.

In spite of the general distribution of Vitamin B in foodstuffs, serious consequences have occurred and are occurring because of insufficient Vitamin B in the diet. This is true particularly in the tropics where polished rice constitutes so large a part of the diet. Hess states that in Manila the death rate due to beriberi for those under one year of age is 430 per 1,000. A quotation from Andrews[15] is pertinent in this connection: "Of all the so-called tropical diseases beriberi probably enjoys the distinction of having the largest literature associated with it, of having been the subject of the most extensive discussion, and of having had the most diverse opinions expressed concerning its etiology, symptomatology and pathology. Nor is this to be wondered at when we consider the number of years the condition has been recognized, its protean manifestations, and the destruction of human life it has wrought.

"Beriberi is world-wide in its distribution and although tropical countries have been more extensively ravaged by it, climate seems to exert little or no influence upon the course of the disease." Andrews found that an autopsy on 219 infants under one year old who had been diagnosed by their physicians as having died from "acute meningitis," "congenital debility," "convulsions," "beriberi," "acute bronchitis" or "enteritis," showed that 124 or 56.6 per cent actually died of a condition which Andrews called beriberi. These infants appeared to be well nourished but they had symptoms which he described as characteristic of beriberi, i.e., labored breathing, high pulse rate, etc.

But the impossibility of infants under one year of age being on a diet of polished rice will occur to everyone. Andrews goes on to explain this for us. He says that in most cases the mothers show symptoms of beriberi, such as pains in the legs, anaesthetic areas or numbness on the legs, lack of coordination in walking, loss of knee jerks and other reflexes, dyspnoea, palpitation and heart murmurs. Their diet is usually white rice and fish or meat, rarely vegetables or fruit. Puppies nursed by these women died after about one month of typical beriberi, showing that their milk was deficient in Vitamin B. People who consume a rather wide variety of foodstuffs apparently show no evidence that there is much likeliness of an insufficient intake of Vitamin B. The literature on the subject would lead one to believe that this is not true to the same extent with the other vitamins, whose distribution is apparently less wide.

Experiments on Vitamin B were first carried out almost exclusively with fowls. If fed on polished rice or other diet lacking in Vitamin B they succumb to polyneuritis within about three weeks. The onset is rather sudden. The legs, wings and neck, in fact the whole muscular system, becomes distorted owing to paralysis and death results within a few days. If not too far advanced the disease can be cured by the administration of Vitamin B.

Funk[16] obtained a vitamin preparation from yeast, 0.004 to 0.008 grams of which brought about a cure of pigeons, prostrated and distorted by polyneuritis, within three hours. It is not believed that Funk's preparation was pure Vitamin B. So the actual amount given was exceedingly small.

When Vitamin B is lacking in young rats' diet, they gradually decline within a few days and die after a number of days, depending upon their resistance. Apparently, the definite polyneuritic symptoms that occur in fowls is unusual in rats. Introduction of Vitamin B into the diet meets with immediate response and the animal at once begins to grow. Many believe that the antineuritic activity demonstrated by feeding fowls is due to a different substance than the growth-promoting factor noted in feeding rats. Others believe that the growth-promoting factor is in reality two substances, one of which is the antineuritic factor.

Goldberger[268] and his coworkers, after an exhaustive study of pellagra, have come to the conclusion that one component of Vitamin B is involved in this disease as well as in the disease of black tongue of dog, which he suggests may be the analog of human pellagra. This component of Vitamin B in yeast is able to withstand steaming in an autoclave under 15 pounds pressure for 2½ hours without any appreciable loss. The yeast loses decidedly, during this steaming, its growth promoting power for young rats.

The effect of Vitamin B on the appetite is quite remarkable. When a dog is fed on a Vitamin B free diet he loses his appetite after some days and finally declines to eat entirely. If now given a concentrated extract of this vitamin in a capsule so he derives no taste from it his appetite will be restored practically to normal in a few hours and he devours the food he previously refused.

VITAMIN C

Scurvy is probably the first nutritional disorder recognized as caused by a lack of some constituent in the diet. This can be ascribed to the fact that the origin of this constituent is, as stated by Chick and Hume[17], the living, actively metabolizing tissues of plants (cabbage, lettuce, spinach, etc.) and to a less degree of animals. It is easy to conceive the conditions under which such products might be lacking in a diet. Vitamin C is found in green leaves, cabbage and salad vegetables, bleached as well as unbleached, tomatoes, onions and the root vegetables, as potatoes, carrots, swedes and others. The fruits, especially the citrus fruits, are considered to be very rich in it. So far as green grasses, turnips, swedes and similar products are utilized in the production of milk, eggs, and meat, the latter also contain Vitamin C. As already stated, however, it has recently been contradicted that the Vitamin C in the diet of the dairy cow has any relationship to the Vitamin C in the milk, another instance of the confusion existing in opinions regarding the vitamins. When seeds sprout, as was first pointed out by Fürst[180], there is an abundant production of Vitamin C. It is generally believed, therefore, that it is the product of the actively metabolizing plant cell. Grijns[181] recorded the fact that the antineuritic property (Vitamin B) of seeds disappeared on sprouting.

It has been found by Parsons[18] that the rat's liver is rich in Vitamin C even in the second and third generation on a scorbutic diet. As it is generally believed that animals do not synthesize or make vitamins, it has been suggested that the rat can get along with the small amount of Vitamin C that exists in foods which have been regarded as being devoid of it. The rat is considered to need very little Vitamin C. Harden and Zilva,[185] Drummond,[186] Sherman and Smith,[176] Lepkovsky and Nelson,[200] all seem to agree that although rats may grow and reproduce on a so-called scorbutic diet, yet they thrive better and reproduction is more prolific with a liberal amount of antiscorbutic vitamin in the diet.

As indicated above, lack of Vitamin C in the diet leads to scurvy in certain species of animals. Vitamin C is therefore known as the antiscorbutic vitamin. Not only in past history but even in modern times scurvy has ravaged armies and, in times of food shortage, even the civilian population of great areas. It is the most characteristic of the nutritional diseases resulting from a diet inadequate in its vitamin content. Hess[2] says of it: "In fact it (scurvy) is the only nutritional disorder brought about by inadequacy of diet which is associated with characteristic pathologic alteration. For we must bear in mind that the nerve degenerations of beriberi are not typical or diagnostic as are the bone lesions of scurvy." This statement was made before the recent developments in rickets.

As concrete examples, we may mention Budd[19], who gives a description of the ravages of the Austrian army in Hungary in the early part of the eighteenth century; and the Medical and Surgical

History of the War of the Rebellion[20] where we find that in the Civil War similar conditions occurred. Even in the World War, Hess and Unger[21] state there were numerous cases of scurvy, both in the army and civilian population. This was least noticeable on the Western Front. Wilcox[22] says there were over 11,000 cases of scurvy in the British Colonial troops in Mesopotamia during the last half of 1916.

Chick and Hume[23] call attention to several outbreaks or epidemics of scurvy among civilian populations following the failure of the potato crop in regions where potatoes are a large item in the diet. These occurred in Ireland in 1847, in Norway in 1904 and in Glascow, Newcastle and Manchester in 1917. Hess[2] ascribes similar properties to the potato as an antiscorbutic when he says: "It is hardly an exaggeration to state that in the temperate zones the development or non-development of scurvy depends largely on the potato crop. To a minor degree this happened in 1914 in various localities in the United States when the potato crop was inadequate."

Neuman[24] and Heubner[25] in Germany and Hess[26] in this country have found numerous cases of scurvy to follow the introduction of the process of milk pasteurization. Hess[27] states that similar results followed in France and Switzerland upon the introduction of the homogenizing process owing to oxidation which resulted from incorporated air. Moreover, we read[28] that mild forms of scurvy are not infrequent in early spring and pass unrecognized, to be cured with the advent of fresh vegetables. In this connection, Hess[29] says: "When we reflect that it usually requires six months before a case of scurvy reaches the phase where it can be recognized clinically, it is clear that the great majority of cases must be latent or rudimentary, and inaccessible to diagnosis by clinical or laboratory methods. It would seem logical to believe that there is a considerable number of infants who for a period of one or more months are unwittingly deprived of the necessary quota of antiscorbutic food, but who are saved from the manifest development of the disorder by a casual and fortunate change in the dietary." In support of this view it may be stated that in feeding guinea pigs, which are commonly regarded as the most susceptible to scurvy, it is a common experience to have them receive enough antiscorbutic to prevent scurvy, but not enough to permit normal growth.

Guinea pigs have always been the classical animals for the production of experimental scurvy because they are most sensitive to the lack of Vitamin C. Rabbits and rats may thrive for months on a diet that will induce scurvy in guinea pigs within three weeks. Recently it has been found by Lopez, Lamba and Porter[29] that young rabbits are not completely nourished when the antiscorbutic vitamin is lacking in the diet, whereas mature rabbits need only very little or none of it. Early symptoms resulting from a lack of Vitamin C in the guinea pig's diet are tenderness and pain in the knee joints. The gums become inflamed, the teeth get loose, and the bones grow weak and are apt to break with very little pressure. Hemmorrhage occurs at the knee joints and the ends of the ribs. Death always results unless the animal is given an antiscorbutic diet before the disease is too far advanced. Even if a cure is effected the scars left by the bone lesions are never completely obliterated.

THE NATURE OF DEFICIENT DIETS

It is probably no exaggeration to state that with a possible exception of scurvy, and more specifically infantile scurvy, no disease occurs among human beings, or is ever likely to occur, as the result of but one single substance lacking in the diet. Stated in another way, there are probably no diets consumed by human beings that can be improved by the addition of one single food constituent only. Furthermore, if other constituents, such as complete proteins and inorganic elements, are not adequately represented in a diet, as well as the proper conditions of sanitation and exercise and sunlight, a low vitamin content will manifest itself much sooner in bringing on the so-called deficiency diseases. For this reason it is an error to ascribe these diseases definitely to a lack of a specific vitamin. In this connection McCarrison[174] summarizes the subject well in the following sentence: "Any infection or debilitating agency which further reduces the efficiency of the cells, and especially the efficiency of the endocrine regulators of metabolism, may, in my view, be a determining factor in the production of any form of deficiency disease so far known to us—be it goitre due to want of iodine, chlorosis due to want of iron, beriberi due to want of Vitamin B, keratomalacia due to want of Vitamin A, scurvy due to want of Vitamin C, or pellagra due to want of protein of good biological value." The experiment by Wiltshire described on page 13 tends to emphasize this view and casts doubt on the close relationship between Vitamin C and human scurvy.

Beriberi is ascribed to a lack of Vitamin B in the diet which often consists largely of polished rice. The addition of Vitamin B in pure form, if it could be so isolated, might temporarily alleviate, cure or prevent beriberi in man or polyneuritis in birds but it would not make polished rice an adequate diet for continued nutritional well-being. By the addition of rice polishings to polished rice, not only Vitamin B is added but a number of other substances, both organic and inorganic, known and unknown, that are of undoubted value as foods. Yeast extract in small amounts may be a temporary curative or preventive for polyneuritis in birds on a diet of polished rice, but it does not make polished rice a satisfactory diet for long-continued nutritional well-being when it is the only food consumed. It is shown on page 18 that the development of rickets is related to several constituents in the diet and also to certain hygenic conditions, such as sunlight and exercise.

Pellagra is classed among the deficiency diseases and recent evidence indicates just what the deficiencies are that cause it. Funk[16] attempts to correlate both in Europe and in America the increase and decrease in the occurrence of pellagra with the increase and decrease in the production and use in the diet of corn or maize. He is of the opinion that the facts regarding this malady can best be explained by attributing it to a lack of some necessary constituent in the diet and that a happy solution is the production of cheap potatoes, cheap meat and fruits. Voegtlin[80] suggests a theory of chronic intoxication but admits the possible importance of vitamins and amino acids. Goldberger[81] emphasizes the importance of animal proteins, milk, eggs and meat as a remedy, but does not exclude the possible importance of vitamins. Wilson[82] states that it is the ultimate result of a deficient supply of protein. Chick and Hume[187] recently produced pellagra-like symptoms in monkeys on diets low in proteins and these were lacking in certain amino acids. The condition was promptly cured by correcting this feature of the diet. Wheeler[178] found that "one supplemental (noon) meal of fresh meat, milk, vegetables, fruit, bread (either wheat or corn bread) and butter was adequate to relieve the symptoms and to prevent recurrence in cases of pellagra of moderate severity in patients continuing in the environment in which the disease had originally developed or had previously recurred."

More than 50 years ago Roussel[88] pointed out that pellagra can be cured by good food and that without it all remedies fail. It is doubtful whether anyone until recently was justified in making a more definite summary of the subject.

Of especial interest is a recent report of Goldberger and Tanner[190] as it illustrates how completely the ideas of a worker in this field may change within a few years. In 1914 Goldberger, Waring and Willets[191], suggesting inclusions in the diet by which pellagra might be avoided, mentioned among other things, "fresh or dried, but not canned beans and peas," "fresh or dried, but not canned fruits." We are unable to gather from his writings upon what grounds he based such a recommendation regarding canned foods. Recently Goldberger and Tanner reported an experiment in which they state, "At least 6 of 11 convicts who volunteered for the experiment and who subsisted on a diet consisting principally of the cereals wheat, maize and rice with pork fat and some fresh vegetables (sweet potatoes, turnips, cabbage and greens), developed evidence which experienced observers recognized as that of pellagra; whereas, of a large number of controls none presented any evidence justifying even a suspicion of the disease."

"Thus, by a process of exclusion, we are led to conclude that of the known dietary essentials the protein factor alone was concerned in our failure to prevent the development of the cases herein cited. And if our interpretations are, as we believe, sound (and if all dietary factors essential in human nutrition are known), the further conclusion may properly be drawn namely, that the dominating role of diet in the prevention and causation of pellagra must be referred primarily to the character of the protein supply."

"Some of the perplexity and confusion will also be prevented if it is not forgotten that the biological quality of a protein and its adequacy in relation to pellagra may, and doubtless frequently do, depend on the plane of intake. In our experience a supplement of not over 40 grams of milk or beef proteins will, for practically all normal individuals, adequately supplement a pellagra producing mixture of proteins from maize, wheat, rice and cowpeas; but 20 grams (representing somewhat over a pint of milk or a quarter of a pound of round steak) may not do so." More recently Goldberger [268] and his coworkers conclude that one of the components of Vitamin B is the anti-pellagra substance and the evidence is being accepted as fairly convincing. If, as Goldberger suggests, black tongue of dog is the analog of human pellagra, we may look for rapid developments in this field.

If these views in regard to pellagra, probably the most serious deficiency disease in this country, are proven to be correct, then canned foods, instead of playing a part in its cause as was first suggested, may prove to be the solution for its cure and prevention. From the work of Hogan (See page 45) we must conclude that canned milk and meat supply proteins with the identical nutritive qualities possessed by the proteins in fresh milk and meat. Whether the consumer uses the fresh or the canned product is then merely an economic question with which we are not here concerned. As it has been shown that the component of Vitamin B which Goldberger now believes to be specifically involved in the prevention of pellagra, is able to resist more severe heat treatment than is ever given canned foods, canned foods may function in supplying it under all conditions.

The wonderful discoveries and remarkable progress in nutritional studies in recent years have appealed to the imagination of the people. They have in many cases been given wrong impressions. A little of this or a little of that, added to their diet, some seem to believe, will result in health and longevity. The true and natural and sure way to successful nutrition is a well-balanced, wide variety of wholesome food products in sufficient quantity for the individual concerned. This is to be especially emphasized because modern views in the field of nutrition are based, to a great extent, upon the results of experiments on various animals and the requirements of different species is far from uniform.

Modern methods of food preservation in times and places of plenty and conservation for times and places of scarcity have this advantage—they make possible a wide variety in the diet at all times. Any method will be successful in so far as it accomplishes this preservation and conservation with the nutritional qualities intact and unchanged. On the other hand, it must be borne in mind that every food product has more than one nutritional factor or constituent. The loss or partial loss of one in a certain process does not condemn the process. If this were true, then we should have to condemn the cooking of vegetables and eat them raw, because a large portion of the antiscorbutic value is lost on cooking. Many vegetables have such a high initial vitamin content that even with appreciable destruction, they still remain rich sources of vitamins. Many are only palatable in cooked form and to eliminate them from our diet would be to materially lessen our vitamin supply.

Vegetables have other valuable qualities to commend them. Undoubtedly, some of these qualities are enhanced and improved by the cooking process (See Expt. 48). Extensive experiments by Jones and associates[201] on the effect of cooking various varieties of peas, beans and lentils, have demonstrated that in all cases the proteins are of much greater value after cooking. Work of this kind has not been extended to other vegetable proteins.

Canned tomatoes have been shown to be rich in all three vitamins. They also contain certain mineral salts and other necessary food constituents, protein, carbohydrates and fats. Cane sugar, on the other hand, is practically a single, chemically pure carbohydrate, devoid of all other food constituents. It is completely burned in the body to form energy which can be supplied by other carbohydrates, by fats or proteins, although it may also stimulate metabolism in certain ways. But even in the face of these facts one is not justified in making a comparison of tomatoes and sugar or in any way implying that one is a better food than the other. Each has its place and is necessary to secure the proper balance in a diet. The preservation of foods is indispensable to supply the essential dietary constituents under modern social and economic conditions.

THE STABILITY OF VITAMINS TOWARD HEAT

VITAMINS A, D AND E

All of our knowledge about vitamins is based on animal feeding tests. In most experiments more than one animal is used and their average behavior toward the test is made the basis of the conclusions drawn. Although this is quite adequate for qualitative questions, it is necessary to keep this condition in mind in discussing the stability of the vitamins toward heat, a determination of which involves a quantitative estimate of the vitamin content of a food before and after heating.

The experimental studies thus far made indicate that the temperatures used in the canning industry are not sufficient to destroy a detectable amount of Vitamins A, D and E in fats. Wherever the experiments described in the following pages show destruction of these vitamins in fats at temperatures used in the canning industry it will be noted that the product was heated in the presence of air, and it is therefore only fair to ascribe the destruction to oxidation, since oxidation is known to be destructive.

In the absence of air, butter fat has been heated 15 hours at 205° F. (Expt. 20), 6 hours at 212° F. (Expt. 18), and 4 hours at 248° F. (Expt. 28) with no loss of Vitamin A as far as could be determined by the methods of experimentation used.

The stability of Vitamin A to heat seems at least as great in natural food products as in butter fat. Yellow maize, chard, carrots, sweet potatoes, squash and alfalfa have been heated for 3 hours under 15 pounds pressure, i. e., 250° F. (Expt. 47), with no loss of Vitamin A. Cabbage has been heated for 1 hour at 248° F. with no loss of Vitamin A (Expt. 52), 2 hours at 248° F. (Expt. 53), and 1 hour at 266° F. (Expt. 54) with only moderate loss. No process for the canned products is so high. One experiment is reported in which cooking cabbage one hour at 212° F. improved its growth-promoting properties (Expt. 48). Spinach and pineapple have their Vitamin A undiminished by canning (Expts. 64 and 67), whereas some destruction is noted in canned artichoke (Expt. 61).

Similar results have subsequently been found in commercially canned peas[265] and peaches[263].

Commercially canned evaporated milk and sweetened condensed milk (Expts. 56 and 59) give evidence of no appreciable amount of Vitamin A being destroyed. Commercially canned tomatoes (Expt. 77) even after drying (considered on a dry basis), have been found to be at least as rich in Vitamin A as is butter fat, which has been regarded as the prototype of substances containing this vitamin.

VITAMIN B

The destruction of Vitamin B, owing to heating, is noticeable sooner when the feeding tests are conducted with fowls than with rats. This is considered evidence by some that Vitamin B is at least two substances, one whose absence is earlier recognized in fowls and the other in rats. It is therefore hard to summarize the experiments in general statements, especially when the discrepancies in experiments by different workers are noted.

The influence of heating yeast extract on the destruction of Vitamin B has been studied with pigeons and with rats. In experiments with pigeons, heating for 1 hour at 212° F. (Expts. 107 and 110) resulted in very little loss of Vitamin B, and heating for 1 hour at 252° F. (Expt. 111) caused a loss of from one-fourth to one-half of the Vitamin B present in the raw product, whereas 2 hours' heating destroyed one-half to three-fourths (Expt. 112). In working with rats, heating for one-half hour at 248° F. (Expt. 113) resulted in considerable loss of Vitamin B, but very little when heated at 212°.

In seeds, Vitamin B seems to be more stable. Heating for 3 hours at 212° F. (Expt. 121) or 4 hours at approximately the same temperature (Expt. 133), or 2 hours at 230° F. (Expt. 126) or 1 hour at 248° F. (Expts. 157 and 160), or 1 hour at 250° F. (Expt. 134) had no destructive effect on Vitamin B of seeds as far as could be detected in feeding fowls. The stimulant for rat growth is less easily destroyed (Expt. 161). Navy beans were heated 1¼ hours at 248° F. (Expt. 149) with no loss in the substance that stimulates rat growth being reported. Some have recorded destruction at lower temperatures, and at higher temperatures and longer periods of heating there is presumably a proportionate loss.

Published experiments pertaining to meat and eggs (Expts. 167 to 182, inclusive) have been so poorly controlled from the standpoint of determining the loss of Vitamin B that no definite conclusion is warranted. The basis for this statement is given in the discussion on page 46. There is no reason to believe that more destruction occurs in these products than in others. It is well to bear in mind that meat, i. e., muscle of beef, and probably that of other animals is not rich in vitamins even in the raw state. It owes its value to other constituents.

Failure to realize that fresh milk may, under certain conditions, vary several hundred per cent in its vitamin content (see page 36) and that heat may affect constituents other than vitamins, has led to many conflicting statements. Evaporated and condensed milk give evidence of no appreciable loss of Vitamin B (Expts. 202 to 205, inclusive). The Vitamin B in milk is relatively stable (Expts. 187, 188, 194 and 204).

Vegetables have not been tested to any extent to determine their loss of Vitamin B at higher temperatures than ordinary cooking temperatures, and these have proved to be without effect. Canned carrots, processed for 2 hours at 212° F. (Expt. 212), or three-fourths hour at 239° F. (Expt. 216), show no appreciable loss. In the case of spinach (Expt. 223) canning and subsequent drying affected the flavor so that rats would not eat as much of it as of dried raw spinach. The spinach could apparently supply the Vitamin B if the rats would eat it.

Vitamin B is generally regarded as being less affected by oxidation than the other vitamins. Attention is again called to commercially canned tomatoes (Expt. 214) as a rich source of Vitamin B as well as Vitamin A, and to canned pineapple (Expt. 221) whose Vitamin B potency is apparently undiminished. Peas, particularly rich in Vitamin B, apparently lose no appreciable amount of it in canning[265]. Likewise, peaches [263] retain most, if not all their vitamin.

VITAMIN C

A guinea pig is generally regarded as needing 1.5 cc. of orange juice daily to supply its needs of the antiscorbutic vitamin (Vitamin C). Taking this into account, oranges have been canned and stored 3 months (Expt. 299), and orange juice has been boiled at least 10 minutes (Expt. 293), and lemon juice 5 minutes (Expt. 300), with no noticeable loss of Vitamin C. Again, orange juice has been heated 1 hour at 212° F. (Expt. 296) and also 1 hour at 266° F. (Expt. 297), with the destruction of less than half of the vitamin present. If the stability is as great in other fruits, the heat treatment employed in the processing of canned fruits does not destroy a detectable amount of Vitamin C. Raspberries and cloudberries (Expt. 294) and rhubarb (Expt. 308) apparently withstand temperatures more severe than those used in processing without any appreciable loss of Vitamin C. In apples and bananas (Expts. 305 and 306), this vitamin seems less stable. By the process now usually employed whereby the respiratory process is utilized to eliminate the oxygen in apples, this fruit is canned with no apparent loss of Vitamin C (Expt. 317).

It was formerly believed that the heating of milk in pasteurization caused the destruction of a considerable amount of its Vitamin C. It has been found recently, however, that this destruction of Vitamin C may be due to oxidation rather than to heat. When milk is heated and stored thereafter in the absence of air, Vitamin C is destroyed to a far less extent than was formerly supposed. This latter factor accounts for some of the discrepancies in Experiments 318 to 343, inclusive. The vitamin content of fresh milk is as important a factor as the process milk receives in canning. More experimental work on evaporated milk is needed to determine to what degree Vitamin C is destroyed by the process. In view of the fact that evaporated milk is processed in the presence of a limited amount of air, it seems possible that it may retain a considerable amount of Vitamin C present in the raw product. No comparison of evaporated milk with the corresponding fresh milk has been made, but it has been found that condensed milk may prevent and cure scurvy in children (Expts. 329 and 332). It is evident, therefore, that condensed milk may retain a considerable amount of Vitamin C, and Experiment 333 indicates that the loss may be inappreciable.

A guinea pig requires 1.0 to 1.5 grams of raw cabbage daily to supply it with Vitamin C. After cooking for 2 hours at 212° F. (Expt. 352), 1 hour at 230° F. (Expt. 353), or 1 hour at 248° F. (Expt. 354), 15 to 30 grams, and sometimes more, were found to be necessary. Experiment 358 with cabbage indicates less loss in canning than in ordinary cooking. Drained canned cabbage retained 30 per cent of its vitamin, but 39 per cent of the can contents was liquor, and was drained off and discarded. It is known that some of the vitamin goes into the cooking water. Figures ranging from 40 to 70 per cent have been reported. If it was equally abundant in the cabbage and liquor, then 39 per cent of the vitamin was discarded. On this assumption the entire contents of the can retained

100/61×30=49 per cent. The loss of Vitamin C found by Delf[1] on cooking cabbage is given in the following tabular statement:

Time of Cooking *Hours*	Temperature *°F.*	Vitamin C destroyed *Per Cent*
1	140	70
1	194	less than 90
1/3	194-212	70
1	212	less than 90
2	212	do 90
1	230	do 90
1	248	do 90
2	248	do 93
1	266	93
2	266	93-97

Even the drained product of this canned cabbage of Experiment 358 retained more of the Vitamin C than cabbage cooked in an open kettle. These figures indicate that the rapid destruction of the vitamin occurs with the initial heating, even at lower temperatures, and subsequent heating does not proportionately add to it. Moreover, they indicate that more destruction may take place in ordinary cooking processes than in canning. This is probably due to the oxidizing effect of the air. Even much more severe heat treatment than is used in processing leaves considerable Vitamin C in cabbage (Expts. 355, 356 and 357). That commercially canned cabbage is several times richer than home cooked, even though the heat treatment is greater, is brought out in Experiments 362 and 363. This may be due to less destruction when heated in a hermetically sealed can, to a richer vitamin content in the raw material or to a combination of the two. These experiments also show no greater destruction when cabbage is heated in a can at 260° F. than at 212° F.

Experiment 375 shows that in the intermittent process used, canned green runner beans, drained, retained 10 per cent of Vitamin C. The liquor, constituting 37 per cent of the contents of the can, was discarded and this may have contained 37 per cent of the vitamin in the can. In that case a total of 16 per cent was not destroyed. This is less loss than is given in the above table for cooking cabbage where less heat was applied. The statement made in regard to cabbage is apparently true for other vegetables, i. e., the lower temperatures produce almost as great destruction as higher temperatures. Experiments 379 to 382, inclusive, on swede juice do not indicate any difference in destruction of Vitamin C between heating at the temperatures of 176°, 212° and 230° F. for a period of 1 hour. A more quantative experiment probably would disclose some difference.

In the case of carrots, age seems to be as important a consideration as cooking. See Experiments 367 to 371. In regard to potatoes, Hess[2] says: "It is hardly an exaggeration to state that in the temperate zones the development or non-development of scurvy depends largely on the potato crop." This statement should be considered in connection with the fact that potatoes are always cooked before eaten (See Expts. 376, 377, 378). There is no reason for the belief that the destruction of the antiscorbutic vitamin in other vegetables is greater than in potatoes. In tomatoes it is undoubtedly less. Canned tomatoes are one of the richest sources of Vitamin C, as they are of the other vitamins (Expts. 372 and 390). Likewise, canned spinach,[211] cabbage,[249] peas,[265] peaches,[263] strawberries,[269] and pineapples[264] have been demonstrated to be excellent sources of Vitamin C.

Since the lower temperatures produce such relatively marked destruction (See discussion on page 48) and, as pointed out by Delf,[188] in cooking sprouted cow-peas, a great part of the destruction of Vitamin C occurs in the first few minutes before any appreciable softening occurs, canned vegetables should have as much Vitamin C as the same vegetables cooked in any other way. A shorter exposure to higher temperatures is less destructive than longer exposure to lower temperature. As oxidation plays such an active role in the destruction of Vitamin C, the cooking of vegetables in the closed can, i. e., processing, would seem the ideal method for its protection during the heating period. Furthermore, Experiment 395 has shown that canned spinach is rich in Vitamin C and that extending the time of heating in the can has no detectable effect in producing vitamin loss, whereas excessively extending the blanch does. There is some data as to the effect of subsequent storing on the vitamin content. It has been found that after three years of storage canned tomatoes[152] are still so rich in Vitamin C that it seems doubtful that any deterioration could have occurred. The storage of canned spinach[270] for three years evidenced no loss of vitamins.

Oranges have been canned and stored for 4 years with no more than 10 per cent loss in Vitamin C.[262] Likewise, a retest of the canned spinach noted in Expt. 395, three years after canning gave no evidence of significant loss of Vitamin C.

THE VITAMINS IN MILK

It is generally accepted that young growing animals are in need of considerably larger amounts of the different vitamins, and are far more apt to suffer sooner and more severely than fully matured animals from a lack of them. Since milk constitutes such a large proportion of the diet of the young, it deserves special consideration in this respect. Moreover, milk has been more thoroughly investigated than any other product and found to vary greatly in its vitamin content. As other products are subjected to more detailed study, we may expect to find similar variation in them. Hess[184] found young carrots much superior to old carrots and slightly green tomatoes inferior to fully ripe tomatoes in antiscorbutic value. Delf[183] reports similar findings in regard to tomatoes.

In 1909 Stepp[84] gave the first definite evidence that milk contained unknown substances, now known as vitamins, necessary for complete nutrition, although he did not call them by that name. He found that a bread and milk diet was adequate for rats and mice. If this diet was extracted with ether and alcohol, and the fat thus removed replaced by fats other than milk-fat, Stepp found that the rats and mice failed to grow. If the alcohol ether extract, after evaporation of these solvents, was returned, growth again resulted. We now realize that Stepp was extracting both Vitamins A and B, but he could not understand that from the knowledge then available.

In 1912 Hopkins[85] found that 2 cc. of milk per day, i. e., from 1 to 3 per cent of the total diet, was sufficient to induce normal growth in rats and mice on a diet of casein, starch, lard, water and a salt mixture—a ration considered to be devoid of vitamins.

In contrast with this, Gibson and Conception[86] could not prevent polyneuritis in grown fowls on a daily ration of 100 cc. of milk and 40 grams of polished rice. Moreover, a complete milk diet for young puppies and pigs proved inadequate for good growth. Cooper[87] found milk far inferior to various animal tissues in curing or preventing polyneuritis in fowls. And in line with this, Osborne and Mendel,[88] in repeated attempts to duplicate Hopkins results, reached the conclusion that rats required at least 16 cc. of fresh milk daily for normal growth and frequently this was insufficient. The substance that the milk did not adequately supply was Vitamin B. This was shown by the fact that a small amount of yeast promoted normal growth when added to the same diet. In the last paper they again demonstrate the inadequacy of 2 cc. and state that they have never been able to duplicate the results of Hopkins.

Daniels, Byfield and Laughlin[39] in pursuance of the findings of Gibson and Conception and Osborne and Mendel, studied the effect of the addition of Vitamin B to the usual diet of modified milk of normal, artificially fed infants from 1½ to 5 months of age. This was added both in the form of an alcoholic extract of wheat embryo and in the form of a vegetable soup made by comminuting turnips, carrots and celery, boiling them until very tender and then straining off the liquid. In every case appetite and growth were stimulated. The authors apparently ascribe this beneficial effect to Vitamin B in the soup, a conclusion not entirely warranted in view of the fact that it contained a number of other constituents.

Hopkins[40] has repeated his earlier experiments in the light of the results of other investigators and found 2 cc. of winter milk per rat daily was inadequate to induce normal growth, but that 2 cc. of summer milk did supply sufficient Vitamin B.

Even as early as 1914 Funk,[16] summarizing the findings of various investigators up to date, stated that vitamins did not occur in milk in constant quantities, that they might be almost completely lacking, if the diet of the mother contained too small an amount of them. He considered it probable that cows produce a milk in winter very deficient in this respect as compared with summer milk. In this connection McCollum[41] stated in 1916 that vitamins "pass into the milk only as they are present in the diet of the mother, and that milks may vary in their growth promoting power when the diets of the lactating animals differ widely in their satisfactoriness for the growth of the young." Direct experimental evidence relating to this has been accumulating in recent years. But, in the meantime, experimenters frequently have neglected the significance of Funk's statement with the consequence that we find in literature very conflicting statements as to the vitamin content of milk.

In regard to Vitamin A in milk and butter, Drummond[42] and his associates found that it varied directly with the amount of this substance in the ration of the cow. Drying up of pasturage in the summer materially reduced Vitamin A in milk and butter.

Failure to realize a possible variation of Vitamin C in milk has led to considerable confusion. Chick[43] and her associates maintain that from 85 to 130 cc. daily, or practically a complete diet of fresh milk is necessary to maintain guinea pigs free from scurvy. Thus she classifies milk among the less valuable antiscorbutics. Milk subjected to any of the commonly used heating processes, they state, is practically devoid of Vitamin C. In contrast to this Hess and Unger[44] found milk powder, prepared by the Just-Hatmaker process in which the milk was heated to 241° F. for a few seconds, an effective antiscorbutic for guinea pigs when fed in amounts equivalent to 80 cc. of raw milk. Moreover, this milk powder was effective in curing infantile scurvy. In Experiment 422 is evidence that milk may be powdered by the spray process and be equal in antiscorbutic potency to the liquid milk from which it came.

Barnes and Hume[45] as well as Dutcher, Pierson and Biester[46] found evidence of a direct relationship between the antiscorbutic value of cows milk and the feed consumed. Hart, Steenbock and Ellis[47] gave a numerical expression to this relationship by showing that 30 to 50 cc. of summer pasture milk was potent as an antiscorbutic for guinea pigs, whereas 75 cc. or more of dry feed milk was necessary. This latter was from a herd that had never received any fresh green vegetable tissue.

An experiment by Hess, Unger and Supplee[48] is even more striking. They worked with a herd of five cows that had been all winter on a diet of ensilage, hay and concentrates. Two months after freshening, these cows were put on a ration of bean meal, oil meal, hominy, gluten meal, bran, kiln dried beet pulp, molasses and straw. After three weeks on this diet the mixed milk was dried by the Just-roller process, during which the milk was heated to 230° F. for a few seconds. The cows were then put on pasture for three weeks and again the mixed milk was dried by the same process. Five guinea pigs, each receiving the equivalent of 80 cc. of fresh milk of the first powder, all succumbed to scurvy within 21 days and died within 56 days, whereas three guinea pigs, receiving a similar amount of the second lot of milk powder, were still alive after 120 days, although two had mild symptoms of scurvy.

Dutcher and his associates[49] report a somewhat similar experiment. They were feeding guinea pigs on a diet of 20 cc. of autoclaved milk and with free access to oats to produce scurvy in them. The milk was received from the university herd which received a grain mixture of corn, barley, oats, middlings, bran and oil meal with silage and a poor grade of alfalfa hay. During the spring months they noticed that guinea pigs on this same diet lived longer than formerly, the symptoms of scurvy were less severe, and many of the animals actually gained in weight, whereas a loss in weight and death would have been expected. The time and temperature at which this milk was heated is not given, but in another paper[50] these same authors use one hour at 120° C. and in a private communication they say that it was probably for 30 to 40 minutes under 15 pounds pressure.

Upon inquiry they learned that the university herd had been turned out to spring pasture about ten days before the improved condition of the guinea pigs was noticed. Thereupon these investigators determined the antiscorbutic value of this summer milk in the raw state and found 20 to 30 cc. sufficient to protect guinea pigs from 90 to 100 days, as against the much larger amounts (80 cc. or more) usually regarded as necessary.

In order to obtain more definite information as to the relationship between milk and the diet of cows, a Jersey and a Holstein, both fresh in December, were fed a vitamin-poor ration from January 17th to June 1st. They were then given the same grain mixture, but had constant access to grass. Judging from feeding experiments with guinea pigs, the authors arrived at the conclusion that "20 cc. of the summer milk were superior in nutritive value and in antiscorbutic potency to 60 cc. of winter milk." They found the milk became slowly and gradually poorer when the cows were put on a vitamin-poor ration, whereas when the change was to a vitamin-rich ration, the milk changed almost at once to an abundant vitamin content. This is evidence that cows will draw on the reserve supply of vitamin, stored in their tissue, to supply their milk with it.

Entirely contradictory to the foregoing, are the findings of Hughes, Fitch and Cave[51] [267], who kept two cows for two years on a ration of pearl hominy, tankage, cottonseed meal, and beet pulp. This is a diet low in all the vitamins, yet both cows gained in weight, improved in appearance, and produced normal calves. According to these investigators the milk was as well supplied with antiscorbutic vitamin as milk of other cows on a ration rich in vitamins, but Vitamins A and B were far more abundant in the latter milk.

It is difficult to reconcile the discrepancies of the results found by Hughes, Fitch and Cave with the findings and fairly unanimous opinions of others. Kennedy and Dutcher[52] have recently published data dealing specifically with the effect of the feed of the cow on Vitamin A and B content of the milk. They conclude that the Vitamin A and B content of cow's milk is entirely dependent upon the occurrence of those vitamins in the ration, but that a vitamin-rich milk is not necessarily correlated with access of the cows to pasture. A winter ration consisting of the proper combination of grains and leafy foods will produce milk rich in Vitamins A and B.

It is probable that vitamins are not the only variants in milk caused by a change of cows from winter ration to summer pasture. Hess[2] states that "It has been found in Victoria that cattle on certain pastures develop paralysis and other infirmities which can be cured by fertilization of soil. In the United States in some areas it is impossible to maintain cattle in good condition until the forage is improved by mineral or animal fertilizers, which illustrates that a deficiency in plant tissues leads to nutritional disorders in animals." McClendon and Henry[53] believe they have evidence that soil fertilization causes a variation in Vitamin B in grains. Their data is preliminary and final conclusions are not justified. Luce[198] claims increased Vitamin A content in milk due to exposure of the cow to sunlight.

In view of the fact that the vitamin content of milk may vary to such a great extent, any statement as to the vitamin content of canned milk which does not consider the variation in raw milk is apt to be misleading. No experiments are available in which the raw milk and the same milk canned are compared.

DISCUSSION OF PUBLISHED EXPERIMENTS

GENERAL DISCUSSION

Tables 1, 2, 3 and 4 have been compiled, largely from data not dealing with canning specifically, since such data were then very limited, in order that as accurate a conclusion as possible may be reached relative to the effect of canning operations on the various food factors known as vitamins. In a few cases the detrimental effect of certain treatments has been shown to be due to a change in other constituents. It is possible that in other cases results have been ascribed to changes in the vitamins when, in reality, other substances are wholly or in part responsible. Errors in this respect are not entirely avoidable because a change in vitamin content in a diet necessitates more or less change in other constituents. This will always be true until vitamins can be isolated. From the consumer's standpoint it is immaterial whether it is a question of loss of vitamin or other detrimental effect.

Some of the experiments in the tables have no apparent relation to canning operations, but many have an indirect bearing which may not be obvious at once. Those concerned in the preparation of foods for serving as well as consumers are interested in the possible effects of all treatments to which foods may be subjected. To make this summary of more general interest, experiments are included that may give any possible information relative to the stability of the nutritional properties of foods, although the discussion throughout this bulletin is limited to those treatments which foods are apt to meet in the canning industry. There are some experiments dealing with products not common in the human dietary and a large number dealing with conditions to which human foods are rarely, if ever, subjected. Relatively few deal directly with canned foods. There is almost a total lack of experiments in which the canned product was compared with the raw product from which it was made. By calling attention to this fact it is hoped investigations of the latter kind may be encouraged.

The real comparison which interests the consumer with respect to foods that must be cooked is how he can obtain them with the highest vitamin potency. Can he accomplish this best by purchasing canned foods, already cooked, or by purchasing the raw foods and cooking them by the usual methods. Experiments 64, 65, 66, 317, 362, 363 and 395 were devised for this purpose and in the case of the items investigated, i. e., apples, cabbage and spinach, the data are decidedly in favor of the canned foods as far as Vitamin C is concerned. These results have subsequently been confirmed in the case of peas [265] and peaches.[263] Such experiments leave no doubt about the idea that there are some fundamental underlying principles in canning which tend to make canned foods richer in Vitamin C than foods purchased raw in the market and cooked as is usual in the home.

Experiments 60, 61, 64, 66 and 67 on Vitamin A and 221 and 223 on Vitamin B indicate that canning has no great effect on these vitamins. This is borne out particularly as regards Vitamin A by a number of other experiments on the general question of its stability toward heat. As regards Vitamin B the evidence is not so conclusive. In these experiments as well as in subsequent ones dealing directly with canning, it is evident that there is not nearly so great reduction in vitamin content during canning as the public has been led to believe. Moreover, the destruction is apparently not so great as in the case of long periods of cooking that are necessary at low temperatures. In this connection the British Medical Research Committee[54] reports as follows: "Over the range of temperature employed in ordinary cooking processes, variation in the temperature employed has a comparatively small influence upon the rate of destruction of the antiscurvy vitamin." Delf,[1] speaking of the effect of different methods of cooking, with special reference to fireless cookers, says: "The least loss of antiscorbutic properties will be obtained by cooking green vegetables for a short time at a higher temperature rather than for a longer time at a lower temperature." It therefore seems reasonable to expect that as experiments are made bearing more specifically on the subject, the vitamin content of canned foods will be found to compare favorably with that of ordinary cooked foods. The tendency in the canning industry is to use shorter periods of cooking at higher temperatures rather than the relatively long periods at lower temperatures, which seem to be the most harmful.

There is naturally a great variation in the degree of accuracy and refinement with which the experiments were conducted by various investigators. In general, the most recent are the most reliable, but this is by no means a safe guide. It would be impossible, however, to attempt to rate them all according to their merits. Attention can only be drawn to a few of the most outstanding features. The statements in the tables must be brief and where definite conclusions are stated, as for example, "no loss," "complete destruction," it is possible that more refined experiments in the future will give slightly different results.

VITAMINS A AND D

The effect of various treatments of Vitamins A and D is given in Table 1, Experiments 1 to 105, inclusive. These experiments are divided into the following groups:

The effect of heat and oxidation on Vitamins A and D in fats.
The effect of cooking processes on Vitamins A and D.
The effect of drying on Vitamins A and D.
The effect of saponification on Vitamins A and D in fats.
Miscellaneous.

The results given in Table 1, except where otherwise stated, as in Experiments 48 to 55, inclusive, 57, 58, 78, 79, 81 to 84, inclusive, 96 and 102, are those obtained by feeding rats. There is no question but that all animals are in need of more or less Vitamin A, especially in the growing period. We know little about the relative amounts of vitamins necessary for different species of animals. In general, it seems that the slow growing species require relatively little Vitamin A. Conclusions reached with the smaller species, therefore, should allow a reasonable margin of safety when applied to man. The two vitamins, A and D, are so closely associated that it is simpler to treat them in one table.

In the earlier literature on the subject, vitamin A was often referred to as being unstable to heat. This was the result of the failure of the earlier investigators to note the effect of oxidation. After this factor was realized and taken into account, there was practical agreement among all as to the stability of vitamin A and the conclusions at the beginning of this bulletin seem conservative in the light of recent experiments. The technic in the later experiments was also far more satisfactory than in the earlier ones. The age of the animal, his general physical condition, the food eaten before the time of the experiment, and other factors, were more carefully scrutinized. The earlier experiments were also conducted mostly on fats. In other food products vitamin A is apparently as stable as in fats, although we have no data as to the effect of oxidation in them.

Especial attention is here directed to the experiments of this table dealing with the effect of saponification. The aim of these experiments was to obtain Vitamin A free from fats. This has made possible the feeding of rats on diets practically without fats. Drummond and Coward[55] (Expt. 93) state that the rats with which they experimented received no more than 0.014 gram of fat daily, and yet grew and reproduced normally.

VITAMIN B

The experiments in Table 2 show the effect of heat on Vitamin B and are grouped under the following topics:

The effect of heat on Vitamin B in yeast.
The effect of heat on Vitamin B in seeds.
The effect of heat on Vitamin B in meat and eggs.
The effect of heat on Vitamin B in milk.
The effect of heat on Vitamin B in vegetables and fruits.
The effect of drying on Vitamin B.
The effect of acids and alkalis on Vitamin B.
Miscellaneous.

Mitchell[56] and Emmet and Luros[57] present evidence that the water-soluble substance (the antineuritic vitamin) concerned in the cure and prevention of polyneuritis in fowls is not identical with the substance which stimulates growth in rats. Funk and Dubin[58] claim to have isolated a substance from the water-soluble vitamin B fraction which is not concerned in stimulating rat growth but which stimulates yeast growth, and have designated it as vitamin D. Eddy and associates[253] have isolated in crystalline form the yeast stimulant, commonly called bios, and have shown it is not the rat growth stimulant or the antineuritic vitamin involved in avian polyneuritis.

Goldberger and coworkers give evidence which indicates that Vitamin B consists of at least two components, both of which are necessary for growth, one of which, probably the antineuritic factor, is materially reduced by steaming under 15 pounds pressure, while the other, which is a curative for black tongue of dogs and pellagra of humans, is little, if at all, affected by 2½ hours of such steaming.

As far as the foods of man are concerned, in the light of the limited knowledge now available, the experiments must be considered as a whole, irrespective of the number of substances that may be in the water soluble vitamin B group or the animals or organisms affected by them. If a certain process exerts a harmful effect on the water-soluble vitamin B in the case of some species of animal, it is a wise precaution to assume that it will have a similar effect on man.

It seems that in the case of vitamin B conclusions have been reached that are scarcely warranted. Reference may be made to the experiments in which the results are based on the curative effect on fowls. It is necessary only to recall that numerous substances have been found to exert such a curative effect. Frequently diets are materially changed in other respects when a change in vitamin B content is the point in question. As an illustration, Experiment 213 may be cited. The paper dealing with this experiment was on the subject of vitamins and the authors implied that the beneficial effect was due to vitamin B in the soup. It is fair to ascribe it partially to the many other constituents, mineral salts, nitrogenous and non-nitrogenous organic materials.

It has been found that vitamins stimulate the appetite. A little vitamin added to a diet, therefore, might increase the food intake and this might in itself have a beneficial effect. Yet vitamins are not alone concerned in appetite. Heating may cause a change in palatability. This was actually demonstrated to be the case in Experiment 223. In the earlier experiments food intake was too often not considered. Moreover, substances other than vitamins may be affected detrimentally by certain treatments. As an example, Experiments 199 to 204, inclusive, may be cited. In this connection, Experiment 134 should be considered as a contrast to Experiment 186. The same heating period on wheat embryo and milk powder had entirely different effects. The author of these experiments ascribes this to a change in some other constituent than vitamin B in the milk used in the ration. It should, of course, be borne in mind that the medium in which a vitamin is heated may have a marked effect on its stability. In this connection it is of interest to note that Hogan[172] has shown that autoclaving proteins (egg white six hours in an autoclave under thirty pounds pressure and casein two hours under fifteen, thirty and forty-five pounds pressure) has no detrimental effect on their nutritive qualities. In the case of beans, peas and lentils, Jones and associates[201] have shown cooking to have a marked beneficial effect on the proteins.

Emmet and Luros[57] cite a number of experiments to show that the destruction of vitamin B by heat is more noticeable when the heated food is tested by means of pigeons than when tested by means of rats and give this as evidence that two substances are concerned in the vitamin B fraction. Among others they cite Experiment 170 with the statement that no destruction was apparent. A comparison of Experiments 169 and 170 seems convincing evidence, however, that no conclusion from them pertaining to vitamins is justifiable. Meat cannot be expected to be a satisfactory diet for fowl and the experiments are evidence that it is not. Experiment 182 bears out this statement. Polished rice lacks vitamin B and is the food most commonly used to produce polyneuritis in fowls. Yet a literal interpretation of Experiment 182 would make it a curative or even preventative for polyneuritis. As a matter of fact, it supplements the high protein foods, meat and eggs, and thus a more normal diet results, but a conclusion as to vitamins is scarcely warranted.

The vitamin content of canned foods was questioned by some investigators, when the vitamins were considered less stable than recent experiments would indicate. Experiments 151 to 154, inclusive, 210 and 254 to 258, inclusive, by Daniels and McClurg[59] were thereby instigated and the conclusion drawn that the experiments "indicate that neither high temperatures nor dilute alkalis at the boiling temperature are very detrimental to the antineuritic vitamins in foods" and that "the note of warning sounded by Chick and Hume[60] to the effect that grave danger may attend the use of large amounts of tinned foods, we believe is unfounded, at least from the standpoint of the antineuritic vitamin content of the food." This view has subsequently been strengthened by Experiments 221 and 223. The note of warning by Chick and Hume[60] was the result of Experiments 106 to 112, 140 to 148, and 179 to 181, inclusive. Chick and Hume[61] replied to this criticism, stating that "beriberi occurred among the British troops in the Dardanelles and Mesopotamia during the early part of the recent war when many individuals were forced to subsist for considerable periods on tinned meat, jam and white bread." This is not a diet that would be suitable for vitamins, even though the meat were raw. Chick and Hume[61] further criticise the results of Daniels and McClurg[59] because the beans which they heated constituted one-half the ration and this is "not a reasonable proposition," although they admit it probably would have prevented beriberi among the British troops. Chick and Hume make no suggestion as to what they would consider a reasonable proposition to replace the tinned meat, nor is it within the scope of this bulletin to make such suggestion. We cannot infer fresh meat, because that, under most war conditions, would be less reasonable than tinned beans. Even then, the meat would have to undergo some cooking process and conditions even in an army kitchen are not sufficiently uniform so that the effect of cooking on the vitamins would be known.

The conclusions of Chick and Hume seem too sweeping inasmuch as they were dealing with the extracts of yeast and wheat germ, products which would scarcely be listed as normal human foods, and with meat, which does not owe its value to its vitamin content under any conditions and should not be relied upon as a source of vitamins. (Compare Experiment 140 with 179.) Moreover, it is generally agreed that the vitamins are more stable in their natural condition than in the form of extracts. The result of Experiments 179 to 181 are not convincing from another standpoint. Chick and Hume did not feed the meat as such but extracted it with alcohol and fed the alcoholic extract. Eddy, Heft and Stevenson[178] maintain that alcohol is a much poorer solvent for vitamin B than water. They cite experiments from which wrong conclusions were drawn because of the erroneous assumption that alcohol accomplishes complete extraction. Furthermore, we have no evidence that vitamin B or other beneficial substance is as readily extracted from cooked as from raw meat. Nor do Chick and Hume's experiments involve a comparison of the vitamin content of the canned product with that of the same product in the raw state or after it had undergone any other cooking process. The criticism that tinned beans would supply sufficient vitamins if they constituted half the diet but that this is an unreasonable proposition is implying that whatever would be used in their stead would supply less vitamins. This is an argument in favor of the tinned beans from the standpoint of vitamin content rather than evidence against the "use of large amounts of tinned foods."

One point of weakness in the work of Daniels and McClurg is pointed out by Chick and Hume. The former fed their rats on a diet 50 to 55 per cent of which was made up of heated beans. Although in this way vitamin B was supplied in sufficient amount, such an experiment does not demonstrate any destruction that might have occurred during the heating process. Daniels and McClurg state, however, that their main interest was to determine whether the heated beans contained any appreciable quantities of the vitamin. A crucial experiment could have been made by feeding varying amounts in the diet to determine the minimal protective dose. The vitamin content of the raw beans or the actual amount of vitamin that is destroyed in cooking (if there is any destruction) is hardly worthy of consideration in connection with the human dietary. Raw beans are not human food and Osborn and Mendel[74] have pointed out that rats declined raw soy beans whereas they ate the cooked food readily and grew normally.

In the case of canned beans the heat treatment is certainly not more severe than they must receive in any cooking process to give them the degree of tenderness necessary for consumption. Therefore we have no reason for believing that the vitamin is destroyed to a greater extent in canning than in any other method of cooking. When the sterilizing time and temperature are greater than is necessary for tenderness, the canned foods are to that extent at a disadvantage. The cooking—i. e., the processing—of canned foods is closely regulated as to time, whereas it is apt to vary in kitchens. Cases have been cited where long cooking in army kitchens apparently resulted in ill effects.

VITAMIN C

The effect of various treatments on Vitamin C is given in Table 3. Experiments 291 to 506, inclusive. The experiments are divided into the following groups:

The effect of heat on Vitamin C in fruits.
The effect of heat on Vitamin C in milk.
The effect of heat on Vitamin C in cabbage.
The effect of heat on Vitamin C in other vegetables.
The effect of drying on Vitamin C in fruits.
The effect of drying on Vitamin C in milk.
The effect of drying on Vitamin C in vegetables.
The effect of oxidation on Vitamin C.
The effect of alkali on Vitamin C.
Miscellaneous.

Orange juice has been the prototype of sources of vitamin C and the guinea pig the classical animal for studying the effect of this substance in the diet. One to one and one-half cc. of orange juice daily is regarded as the amount necessary to protect a guinea pig against scurvy. Unless this minimum amount was fed it is obvious that some destruction could occur before it was made manifest by the animals concerned. Judging the experiments with orange juice as a whole it must be concluded that vitamin C is so stable in this acid medium that there would be no appreciable destruction at the temperatures to which fruits are subjected during processing. Experiment 299 is a specific instance. In spite of the results of Experiment 298, the natural acidity is generally regarded as extremely important in the stability of vitamin C, although the most recent work indicates that there is less in this idea than has been supposed.

The effect of oxidation in the destruction of vitamin C has not always been realized. The same is true of the great variation in the amount of vitamins in milk owing to a difference in the feeds consumed. The experiments with milk show many discrepancies which are explainable in the light of these discoveries. Unless the variation of raw milk, which may be several hundred per cent, is taken into account, no definite statement in regard to vitamin C in milk receiving any heat treatment is warranted. The destruction of vitamin C in milk is probably more marked than in the acid fruits and probably corresponds more closely to that taking place in vegetables. Vitamin C in vegetables undoubtedly is destroyed more or less by any method of cooking. Yet scurvy is said to increase and decrease as the potato crop decreases and increases, and potatoes are always thoroughly cooked. This is probably owing to the fact that potatoes constitute a very large part of the food of those whose diet is apt to be limited.

Judging from the available data there does not seem to be any marked difference between cabbage, carrots, potatoes, etc., as antiscorbutics. Experiment 489 indicates raw potatoes and cabbage are about alike. Experiment 379 gives 2.5 cc. of swede juice as the minimum necessary for a guinea pig as against 1.5 grams of cabbage, but a study of Experiments 489 to 492 indicates that raw juices are subject to rapid deterioration presumably because of oxidation and enzymatic activity. It would be unfair, therefore, to rate swedes as of less antiscorbutic value than cabbage.

In view of the susceptibility of vitamin C to oxidation it is necessary to determine the effect of this factor in the cooking of vegetables. Until this is taken into account and the methods are more refined, variations in vegetables of about the same degree of acidity are no greater than can be accounted for by experimental error. Variation due to age, as noted in carrots, does not seem to occur in the case of potatoes, as it is said that potatoes retain their antiscorbutic vitamin throughout the winter. Potatoes have not been systematically studied in this respect, however.

The velocity of most chemical reactions is doubled or more, for each rise in temperature of 18° F. (10° C.). The destruction of vitamin C does not follow this law as first pointed out by Delf.[1] According to LaMer,[62] between 140° F. and 176° F., a rise in temperature of 18 degrees, causes only 1.2 times greater destruction for a given time, whereas between 176° F. and 212° F., a rise in temperature of 18 degrees, causes only 1.1 greater destruction. To give a concrete example, if 30 per cent of vitamin C were destroyed in 1 hour at 158° F. in a given substance, at 176° F. 1.2 times 30 per cent, or 36 per cent, would be destroyed in 1 hour. Or, again, if 50 per cent of vitamin C were destroyed in 1 hour at 194° F., in 1 hour at 212° F. 1.1 times 50, or 55 per cent, would be destroyed. It is unfortunate that similar data were not obtained above 212° F. But if the same general relations hold at higher temperatures, then if a destruction of 50 per cent occurs at 212° F. there will be less than 60 per cent destroyed at 250° F. in the same time of heating. Or, stated in another way, 60 minutes at 212° F. will cause a destruction equal to 50 minutes at 250° F. We do not know that this relation holds at higher temperatures, but at present we have nothing else to guide us.

Sterilization, on the other hand, is a very different matter. Spore-bearing organisms whose sterilization requires several hours at 212° F. require only a few minutes at 250° F.; or those requiring 25 to 30 hours at 212° F. require only 15 to 20 minutes at 250° F. From the standpoint of retaining the maximum vitamin content, this is an argument in favor of sterilization at high temperatures for a short period of time. Under these conditions, sterilization is rapid, but the destruction of the vitamin is not much more marked than at lower temperatures.

Experiments 450 to 473, inclusive, definitely illustrate the effect of oxidation on Vitamin C. A comparison of Experiment 453 with Experiment 291 shows that the storage of orange juice in a refrigerator is about as destructive as heating it for 45 minutes at 230° F.

A comparison of Experiments 450, 451, and 452 shows that the same is true with respect to milk. On first thought, Experiment 458 may seem a contradiction of Experiment 453. But bubbling air through orange juice for only 2 hours should not have a materially greater effect than simply exposing it to air, because orange juice would be apt to hold as much oxygen in solution as would react in that period of time. Two hours at room temperature is scarcely sufficient time to make the action of air noticeable at low temperatures. Convincing evidence that oxidation is the major factor causing destruction and that Vitamin C is relatively stable toward heat has been presented by Kohman, Eddy and Carlsson,[194] who showed that when the oxygen was removed from apples by the respiratory process they could be canned without any loss of Vitamin C. Pumping out the oxygen and replacing it with nitrogen afforded only slight protection, showing that either the small amount of oxygen in commercial nitrogen or some form of combined oxygen was sufficient to destroy the vitamin. These results are substantiated by Eddy and Kohman,[249] who found processing cabbage after canning exerted no greater destruction at 260° F. than at 212° F., the time being equal, and by Eddy, Kohman and Carlsson,[194] who showed that processing spinach for 120 minutes at 248° F. caused no greater destruction than processing only for 70 minutes. Likewise, they found that processing canned peas [265] for 50 minutes at 250° F. did not cause an appreciably greater destruction of Vitamin C than processing for 25 minutes. Likewise, they found that heating canned peas to boiling in a sauce pan promptly after opening caused no further destruction. This is explainable on the basis that a freshly opened can of food is devoid of dissolved oxygen. The initial loss of Vitamin C noted was presumably due to oxidation resulting from traces of oxygen or other oxidizing substances which were used up early in the process.

VITAMIN E

Only a few experiments on the stability of Vitamin E are recorded in the literature. These are given in table 4, from which it appears that this is more stable than any of the previously discovered vitamins.

RECENT EXPERIMENTS

Since compiling the appended tables for an earlier edition, the results of several experiments with canned foods have been published.

The vitamins in strawberries[269] were found to be unaffected by the canning process and by subsequent storage over a considerable period. In feeding experiments no difference was observed in the vitamin C content of raw strawberries purchased daily on the New York City markets and of canned strawberries packed in Oregon 14 to 18 months prior to the feeding period and fed simultaneously. In both cases the daily feeding required for protection against scurvey and normal growth of the guinea pig was between 2 and 3 grams. No difference was observed in the Vitamin A and B content of the raw and the canned strawberries.

In another experiment[270] canned spinach was re-tested approximately 3 years after canning. The results indicate there was no appreciable loss of vitamins during this period.

Craven and Kramer[271] in an extensive experiment with home canned Kieffer pears concluded that the antiscorbutic factor in pear is destroyed in the open-kettle method of home canning. This was shown by the fact that the animals fed open-kettle method pear lived on the average no longer than the expected survival period when the basal diet alone was given.

"The antiscorbutic factor in pear is not completely destroyed by the cold-pack method of home canning. In no case, however, did the animals fed cold-pack pear survive the experimental period of 90 days."

Subsequently commercially canned Kieffer pears[272] were fed in the same laboratory by the same experimenters. A series of lots of Kieffer pears canned to bring out the effect of oxygen was included. Some of the pears were canned at the time of harvesting when they were still hard and green, as well as later after they had mellowed and ripened. From these experiments the following conclusions were drawn:

"In contrast to the results reported with home-canned pears in which vitamin C was almost completely destroyed by the open-kettle method and largely by the cold-pack method, Kieffer pears at the time of harvesting when they were still hard and green, were commercially canned with no apparent loss of vitamin C, provided the oxygen was removed by a suitable procedure. Even when no particular pains were taken to remove this oxygen, beyond those commonly practised in commercial canning, the loss of vitamin C was not great, as it required 20 to 30 grams to be the approximate equivalent of 15 to 20 grams of raw pears.

"Allowing the Kieffer pears to ripen and mellow previous to canning resulted in a commercially canned product in which the vitamin C was appreciably lower."

In the same report are given the results of feeding experiments on a series of lots of commercially canned Bartlett pears. The following may be quoted from the summary:

"The Bartlett pears were canned and fed raw only in the ripe state. The vitamin C content of the canned Bartlett pears was approximately that of the canned ripened Kieffer pears. Animals receiving 15 grams of canned Bartlett pears were comparable to those receiving 15 grams of raw. This suggests that possibly the lower vitamin C content of canned ripened Kieffer pears as compared with the canned green pears is to be ascribed to the ripening and mellowing process rather than to the effect of canning, a condition found to be true with apples.

"Bartlett pears, raw or canned, are relatively low in vitamins A and B, 5 to 7 grams per rat per day in experiments conducted according to the method of Sherman being sufficient to maintain life without significant growth over a 60-day period, but there was a vitamin deficiency manifest in all the animals receiving these amounts."

The subject of vitamins in canned foods has been of much interest in recent years as evidenced by the publication of numerous popular and semi-popular articles. Among these mention may be made of an article by E. V. McCollum[273] printed in the June, 1928, issue of the Health Bulletin, Raleigh, N. C., which discusses canned foods in the daily diet. The following quotation will indicate the viewpoint of the article:

"Now comes the scientific investigator who shows us the fallacy of hasty reasoning from the analogy with ordinary cooked foods, which have lost through destruction most or all of their vitamin C, to the conclusion that canned foods, heated even more thoroughly, have also lost their vitamin C content. There are special features in the canning process which preserve a nutrient principle which ordinary cooking destroys.

"As for the other vitamins in canned foods, it may be said with confidence from data available, that these are not destroyed in canning to an appreciable extent. The high favor of canned foods among consumers everywhere is justified by the results of nutritional research."

TABLE 1.—THE STABILITY OF VITAMINS A AND D.

The Effect of Heat and Oxidation on Vitamins A and D in Fats.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
1	Live steam passed through 2½ hours.	Butter fat.	No loss of Vitamin A indicated when rats' ration contained 18 per cent butter fat.	Osborne and Mendel.[63]
2	Stored 15 months in light and dark at 64° F. and in dark at 46° F.	do.	No loss of Vitamin A noticeable.	Osborne and Mendel.[64]
3	Heated 4 hours at 212° F.	do.	Five per cent raw fat in ration better than 12 per cent heated fat.	Steenbock, Boutwell and Kent[65]
4	Aerated 12 hours at 212° F.	do.	Total loss of Vitamin A.	do.
5	Steam digested	Cod liver.	Cod liver oil therefrom was rich in Vitamin A.	Drummond[66]
6	Hardened by heating in presence of nickel and hydrogen 4 hours at 482° F.	Whale oil.	Total loss of Vitamin A.	Drummond[67]
7	Heated 4 hours at 482° F.	do.	Total loss of Vitamin A.	do.
8	Heated 4 hours at 212° to 302° F.	do.	Most of Vitamin A lost.	do.
9	Hardened by heating in the presence of nickel and hydrogen 4 hours at 482° F.	do.	Twenty per cent unheated equivalent to 8 per cent butter fat in diet, whereas 20 per cent hardened oil showed no evidence of containing Vitamin A.	Drummond[68]
10	Heated 4 hours at 482° F.	do.	Vitamin A totally destroyed.	do.
11	Heated 1 to 4 hours at 212° F.	Butter fat.	Vitamin A destroyed.	do.
12	Heated 4 hours at 122° to 158° F.	do.	Vitamin A destroyed.	do.
13	Heated in air 3 weeks at 99° F.	do.	Vitamin A partially lost	do.
14	Heated in air 3 weeks at 99° F.	Whale oil.	Vitamin A mostly lost.	do.

Effect of Heat and Oxidation on Vitamins A and D in Fats—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
15	Six to 8 hours exposure to ultra-violet rays when air is not excluded.	Butter fat, Whale oil, Cod liver oil.	Vitamin A totally destroyed.	Zilva.[69]
16	Ten hours treatment in dark with ozone.	do.	Vitamin A totally destroyed.	do
17	Sixteen hours exposure to ultra-violet rays in absence of air.	do.	No loss of Vitamin A.	do.
18	Live steam passed through 6 hours.	Butter fat.	No loss of Vitamin A; 0.2 gram fed daily.	Drummond and Coward.[70]
19	Fifteen hours exposure to air in shallow dishes at 205° F.	do.	Vitamin A practically all destroyed.	do.
20	Heated 15 hours at 205° F. in absence of air.	do.	No loss of Vitamin A.	do.
21	Heated 3 hours in air in shallow dishes at 205° F.	do.	Vitamin A practically all destroyed.	do.
22	Heated 3 hours at 205° F. in absence of air.	do.	No loss of Vitamin A.	do.
23	Heated 6 hours in air at 122° F.	do.	Vitamin A practically all destroyed.	do.
24	Heated 6 hours at 122° F. in absence of air.	do.	No loss of Vitamin A.	do.
25	Stored 3 weeks at 99° F. in shallow dishes in air in light and dark	do.	Vitamin A practically all destroyed.	do.
26	Stored 3 weeks at 99° F. in closed vessels in light and dark.	do.	No loss of Vitamin A.	do.
27	Crude and purified.	Palm kernel oil and ground nut oil.	No difference in Vitamin content of crude and purified; 15 per cent fed in diet.	Hopkins.[71]
28	Heated 4 hours in autoclave at 248° F.	Butter fat.	No loss of Vitamin A.	do.

Effect of Heat and Oxidation on Vitamins A and D in Fats—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
29	Heated 4 hours in oil bath at 248° F. with air bubbled through 1 hour.	Butter fat.	Slight loss of Vitamin A.	Hopkins.[71]
30	Heated 4 hours in oil bath at 248° F. with air bubbled through 2 hours.	do.	More loss of Vitamin A than in experiment 29.	do.
31	Heated 4 hours in oil bath at 248° F. with air bubbled through 4 hours.	do.	Practically all Vitamin A destroyed.	do.
32	Heated 16 hours in oil bath at 248° F. with air bubbled through 16 hours.	do.	More complete destruction of Vitamin A than in experiment 31.	do.
33	Air bubbled through 12 hours at 176° F.	do.	About the same loss of Vitamin A as in experiment 31.	do.
34	Kept at 59° to 77° F. 3 months in thin layer exposed to air.	do.	Practically all Vitamin A destroyed.	do.
35	Rendered by heating 35 minutes at 180° F.	Cod liver oil.	Two-tenths to 0.5 per cent in rats' ration of oil rendered thereby supplied sufficient Vitamin A. Cod liver oil richer in Vitamin A than any butter fat.	Steenbock, Sell and Buell.[72]
36	After bubbling air through at boiling water temperature 12 to 20 hours.	Cod liver oil.	Still possesses its calcium deposition properties in original concentration though the anti-zerophthalmic properties are lost.	McCollum, Simmonds Becker & Shipley.[202]
37	Six hours exposure to ozone in dark.	do.	Destroyed Vitamin A.	Zilva.[203]
38	Air passed through at 248° F. for 18 hours.	do.	do.	do.

Effect of Heat and Oxidation on Vitamins A and D in Fats—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
39	Heated while air was bubbled through at 248° F. for 0, 6, 12, 18 and 24 hours.	Cod liver oil.	Minimal protective dose for rickets was 3.3, 9.0, 20.2, 78.7 and more than 450 mg. respectively while the minimal growth promoting dose was 2.2, 7.9, 50.6, more than 450 and more than 1000 mg. respectively.	Goldblatt and Zilva.[204]
40	Ten hours of bubbling air 50 L. per hour through 400 cc., 9 cm. in dia. at 212° F.	do.	Not all Vitamin A was destroyed.	Steenbock and Nelson.[205]
41	Twenty to forty hours bubbling air at 212° F.	do.	Destroyed all Vitamin A.	do.
42	Rendered at 212° F. for 10 hours.	Sperm oil from meat and blubber and one sample of whale oil.	Author contradictory, stating head oil, which gave poorer results than meat or blubber oil, is inferior "since method of preparation (50 lbs. steam) was not calculated to produce great destruction." The three samples of whale oil were assumed to be originally of equal value, but since the two samples rendered under 50 lbs. pressure gave poorest results, author states "much deterioration would be expected by method of preparation."	Delf.[206]
43	Rendered under 50 lbs. steam pressure.	Sperm oil from head and 2 samples of whale oil.	do.	do.

The Effect of Cooking Processes on Vitamins A and D.

44	Boiled.	Egg.	Ether extract of yolk contained normal amount of Vitamin A.	McCollum and Davis[73]

Effect of Cooking on Vitamins A and D—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
45	Heated 3 hours on steam bath, then dried at 176° to 194° F.	Soy bean meal with water to make mash.	Contained Vitamin A. No loss recorded, although not definitely determined.	Osborne and Mendel.[74]
46	Heated 30 to 40 minutes at 250° F.	Soy bean.	Contained considerable Vitamin A. No loss recorded, although not definitely determined.	Daniels and Nichols.[75]
47	Air dried, then soaked, autoclaved 3 hours at 250° F. and again air dried.	Yellow maize chard, carrots, sweet potatoes, squash, alfalfa.	In the raw state, 88, 5, 15, 15, 15 and 10 per cent, respectively, in rats' ration were minimum amounts that would supply sufficient Vitamin A. After this treatment Vitamin A was supplied equally as well by these amounts.	Steenbock and Boutwell.[76]
48	Steamed 1 hour at 212° F.	Green cabbage.	Thirty grams daily per guinea pig gave better growth than like amounts of raw. No loss of Vitamin A indicated.	Hume.[77]
49	Steamed 2 hours at 212° F.	do.	Fifteen grams daily per guinea pig. No loss of Vitamin A indicated.	do.
50	Blanched 3 minutes in dilute sodium bicarbonate, packed in enameled cans, filled with boiling water, closed and processed in boiling water 1½ hours. Temperature in centre of can was between 194° F. and 212° F. for 1 hour.	Cabbage.	Equivalent of 15 grams of original cabbage daily per guinea pig supplied enough Vitamin A if liquor was fed.	Campbell and Chick[146]

Effect of Cooking on Vitamins A and D—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
51	Cooked at 212° F. 1 hour and 2 hours.	Cabbage.	Fifteen or 30 grams per guinea pig per day produced normal growth. No evidence of loss of Vitamin A.	Delf.[1]
52	Cooked 1 hour at 248° F.	do.	Fifteen or 30 grams per guinea pig per day produced normal growth. No evidence of loss of Vitamin A.	do.
53	Cooked 2 hours at 248° F.	do.	Fifteen grams per guinea pig daily gave evidence of only moderate loss of Vitamin A.	do.
54	Heated 1 hour at 266° F.	do.	Fifteen grams per guinea pig daily gave evidence of only moderate loss of Vitamin A.	do.
55	Heated 2 hours at 266° F.	do.	Fifteen grams daily per guinea pig indicated a distinct loss of Vitamin A.	do.
56	Commercially canned.	Evaporated milk.	The fat from this was very effective in relieving rats of xerophthalmia.	McCollum.[78]
57	Heated 1 hour at 266° F.	Hay.	Supplied Vitamin A for guinea pigs.	Hume[77]
58	Heated ½ hour at 250° F.	Oats 60 per cent, alfalfa hay 40 per cent.	Guinea pigs grew well on this diet with 3 cc. orange juice to supply antiscorbutic, showing the Vitamin A of the alfalfa was not destroyed.	Dutcher, Harshaw and Hall.[7]
59	Commercially canned.	Evaporated and sweetened condensed milk.	Retained the Vitamin A in almost its original potency.	McCollum.[8]
60	Canned and stored "many" months.	Tinned beef.	When made from grass-fed animals the fat was often rich in vitamins.	Drummond.[207]

Effect of Cooking on Vitamins A and D—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
61	Raw, canned and processed 1 hour under 15 lb. pressure, and also on 3 successive days in boiling water for 1 hour.	Globe Artichoke.	Some Vitamin A destruction is noted by author but data appears inconclusive.	Morgan and Stephenson.[208]
62	Commercial and home made.	Orange and lemon marmalades and candied lemon peel.	Commercial products appreciably lower in Vitamin A than home-made items, but fed on equal weight basis irrespective of sugar content.	Morgan & Chaney.[209]
63	Boiling for 20 minutes.	Egg yolk.	Does not diminish antirachitic potency.	Hess and Weinstock [210]
64	Raw.	Spinach.	0.26 mg. per day per rat supplied Vitamin A for normal growth.	Eddy, Kohman and Carlsson.[211]
65	Home cooked 15 min. in a covered kettle.	do.	do.	do.
66	Canned by blanching 1 to 5 min. and processing 70 to 120 min. at 240° F.	do.	do.	do.
67	Raw and canned.	Pineapple.	Gave equal growth curves when 5 grms. daily supplied Vitamin A for rats. Ten grams daily did not improve the growth curves.	Miller.[212]
68	Raw, home and pressure cooked, canned and dried.	Spinach.	Fed as a source of both Vitamin A and B thus making conclusions difficult to draw. Also water content of canned spinach was ignored.	Stanley and Stillman.[213]

The Effect of Drying on Vitamins A and D.

69	Dried at 99° F. in hot chamber, stored 2 to 3 weeks in closed vessel.	Cabbage.	Eighty-six per cent of Vitamin A lost.	Delf and Skelton.[79]

The Effect of Drying on Vitamins A and D—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
70	Ground and dried at room temperature.	Sweet potatoes, carrots.	Fifteen per cent in rats' ration supplied Vitamin A. Loss not indicated.	Steenbock and Gross.[80]
71	do.	Rutabaga dasheen, red beets, parsnips, potato.	Fifteen per cent in rats' ration was a total failure as a source of Vitamin A. Loss not indicated.	do.
72	do.	Mangel.	Twenty-five per cent in rats' ration was a total failure as a source of Vitamin A. Loss not indicated.	do.
73	do.	Sugar beet.	Eighty-three per cent in rats' ration was a total failure as a source of Vitamin A. Loss not indicated.	do.
74	Dried at room temperature.	Lettuce, spinach, chard, alfalfa, clover.	Five per cent in rats' ration supplied enough Vitamin A for normal growth and reproduction. Loss not indicated.	Steenbock and Gross.[81]
75	do.	Cabbage.	Fifteen per cent in rats' ration was inadequate as a source of Vitamin A. Loss not indicated.	do.
76	Dried in large drier with air current at 122° to 158° F.	Clover, alfalfa, grass, spinach.	Twenty-five to 50, 70, 42 and 66 milligrams, respectively, of an ether extract per rat daily supplied sufficient Vitamin A. Loss not indicated.	Osborne and Mendel.[83]
77	do.	Spinach, carrot, canned tomatoes.	One-tenth gram per rat daily supplied sufficient Vitamin A. The tomato was richer in Vitamin A than butter fat.	do.
78	Untreated.	Fresh green oats.	Gave positive calcium balance in milking and dry goats.	Hart, Steenbock and Hoppert.[84]
79	Air dried out of direct sunlight.	Fresh green oats.	Retained same property.	do.
80	Commercially dried.	Milk.	Vitamin A content was undiminished.	Hume.[77]

The Effect of Drying on Vitamins A and D—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
81	Cured under caps and out of long exposure to sunlight.	Alfalfa hay.	Liberally milking cows are enabled to maintain calcium and phosphorous balance.	Hart, Steenbock, Hopper and Humphrey [214]
82	Cured in the windrow for 4 days with exposure to air and light.	do.	Milking cows cannot maintain calcium and phosphorous balance.	Hart, Steenbock, Hopper, Bethke and Humphrey [215]
83	Several months old.	do.	Maintained positive calcium balance in milking cows.	Gaessler and McCandlish.[216]
84	One and one-half years old.	do.	Did not maintain calcium balance in milking cows.	do.
85	Desiccation by suitable process.	Orange.	Vitamin A may be conserved.	Osborne and Mendel.[217]
86	Dried.	Thompson seedless, loose muscat or seeded muscat raisins.	Contain no Vitamin A.	Dutcher and Outhouse. [218]
87	Air dried or dried at 176–185° F.	Sweet potatoes, carrots and cabbage.	Contained Vitamin A in proportion to pigment content.	Steenbock and Sell.[219]
88	Dried.	Spinach.	Contained Vitamin A but not antirachitic vitamin.	McClendon. [220]
89	Dried for 15 to 18 hours at 115° to 160° F.	Pumpkin.	No appreciable loss of Vitamin A.	Morgan and Francis.[221]
90	Drying.	Egg yolk.	Markedly reduces the antirachitic vitamin.	Hess and Weinstock.[210]

The Effect of Saponification on Vitamins A and D in Fats.

91	Alcoholic saponification.	Butter fat.	Vitamin A resisted saponification and could be transferred to olive oil.	McCollum and Davis.[85]
92	Alcoholic saponification.	Ether extract of alfalfa.	Non-saponifiable product rich in Vitamin A and pigment was obtained.	Steenbock and Boutwell.[86]

The Effect of Saponification on Vitamins A and D in Fats—Cont'd

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
93	Alcoholic saponification.	Fresh liver oils and extracts from green plant tissues.	Non-saponifiable fraction extraordinarily rich in Vitamin A. Supplied with Vitamin A in this manner, rats grew and reproduced without fat.	Drummond and Coward.[221]
94	Boiling 1 hour or at 95° F. for 4 hours in 20 per cent alcoholic potash.	Butter fat.	Vitamin A in the non-saponifiable residue was not destroyed.	Steenbock, Sell and Buell.[222]
95	Rigorous alcoholic saponification.	Cod liver oil.	The antirachitic factor is not injured.	Zucker, Pappenheimer and Barnett.[223]

Vitamins A and D. Miscellaneous.

96	Stored 9 years at 2 to 25° F.	Fat pork (25 % fat).	Adequate in Vitamin A for young fowls.	Wright.[224]
97	Storage for 2 years in absence of oxygen.	Cod liver oil.	Did not lose its Vitamin A potency.	Drummond, Zilva and Coward.[225]
98	In presence of oxygen.	do.	Vitamin A somewhat reduced.	do.
99	Emulsified with Irish moss or gum acacia.	do.	Vitamin A potency reduced 50% probably due to oxidases.	do.
100	Stored at low temperature for 6 mo. and 1 year.	do.	No loss in Vitamin A.	Holmes.[226]
101	Rendered from fresh livers and from livers rotted 4 months and rotted 8 months.	do.	The order of Vitamin A content was $1:\frac{1}{3}:\frac{1}{12}$.	Holmes.[227]
102	Enough formaldehyde added to prevent souring at room temperature for 48 hours (1 p.p. 2000).	Milk.	Growth curves with chicks same as with untreated milk.	Bleile and Seymour.[228]
103	Hydrogenated.	Cod liver oil.	Apparently no destruction of antirachitic or growth promoting vitamin.	Dubin and Funk.[229]

Vitamins A and D, Miscellaneous—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
104	Irradiated with quartz mercury vapor lamp.	Various rations.	Rations lacking the antirachitic vitamin were made growth promoting.	Steenbock and Black.[195]
105	Heated 45 minutes at 205° F. or dried at 205° F.	Irradiated rations.	Did not lose their growth promoting properties.	do.

TABLE 2.—THE STABILITY OF VITAMIN B.

The Effect of Heat on Vitamin B in Yeast.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
106	Unheated.	Yeast extract.	Minimum amount to cure 300 to 400 gram pigeon of polyneuritis was 1.5 to 2.0 grams.	Chick and Hume.[23] [86]
107	Heated 1 hour at 212° F.	do.	Minimum amount to cure 300 to 400 gram pigeon of polyneuritis was 2.0 to 3.0 grams.	do.
108	Heated 1 hour at 252° F.	do.	Minimum amount to cure 300 to 400 gram pigeon of polyneuritis was 2.5 to 3.0 grams.	do.
109	Heated 2 hours at 252° F.	do.	Minimum amount to cure 300 to 400 gram pigeon of polyneuritis was 5.0 grams.	do.
110	Heated 1 hour at 212° F.	do.	Very little loss of Vitamin B for fowl.	Chick and Hume.[87]
111	Heated 1 hour at 252° F.	do.	For fowls ¼ to ½ of Vitamin B was lost.	do.
112	Heated 2 hours at 252° F.	do.	For fowls ½ to ¾ of Vitamin B was lost.	do.
113	Heated ½ hour at 212° and 248° F.	do.	Very little loss in Vitamin B for rats heated at 212° but considerable at 248°.	Drummond[88]
114	Heated at 221° F. in current of air until dry.	Baker's yeast.	No loss in Vitamin B for rats.	Hawk, Fishback and Berguin.[89]
115	Heated ½ hour at 250° F.	Yeast extract.	Small loss of Vitamin B for yeast.	Williams[90]
116	Heated 2 hours and also 6 hours at 248° F.	Fullers earth activated with yeast extract.	No longer cured polyneuritis in pigeons but stimulated rat growth.	Emmet and Luros.[57]
117	Heated 2 hours and also 6 hours at 248° F. in dry heat.	do.	Properties for curing polyneuritis in pigeons partially lost.	do.
118	Heated 2 hours and also 6 hours at 248° F.	Yeast extract.	Did not cure polyneuritis in pigeons but stimulated rat growth.	do.
119	Autoclaving at 248° F. for 3 to 4 hours.	Yeast.	Some destruction of Vitamin B.	Karr.[230]

The Effect of Heat on Vitamin B in Seeds.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
120	Unheated.	Unmilled rice, barley, oats, rye, millet.	All protected from polyneuritis.	Eykman.[91]
121	Heated 3 hours at 212° F.	Unmilled rice.	No symptoms of polyneuritis in hens after 3½ months.	do.
122	Heated 2 hours at 239° F.	do.	Polyneuritic symptoms in hens in 73 days.	do.
123	Heated 2 hours at 257° F.	do.	Polyneuritic symptoms in hens in 18 days. No prophylactic effect.	do.
124	Heated 2 hours at 239° F.	Unmilled barley.	One hen showed polyneuritic symptoms in 3 weeks, the other in 7 weeks.	do.
125	Heated 2 hours at 275° F.	do.	Two hens showed polyneuritic symptoms in 3 weeks.	do.
126	Heated 2 hours at 230° F.	Oats, unhulled.	Protected hens from polyneuritis.	do.
127	Heated 2 hours at 257° F.	do.	Symptoms of polyneuritis in hens after 17 and 19 days.	do.
128	Heated 2 hours at 239° F.	Rye.	After two months 2 hens showed symptoms of polyneuritis.	do.
129	Heated 2 hours at 257° F.	Millet.	One hen showed symptoms in 26 days.	do.
130	Heated 2 hours at 248° F.	Unmilled rice, Katjidge beans.	Total loss of anti-polyneuritic effect toward fowl.	Grijns.[92]
131	Heated ½ hour at 248° F.	Dried peas, unmilled barley.	No loss in Vitamin B for pigeons.	Holst.[93]
132	Unheated.	Polished rice, 77.4%; Wheat embryo, 13.3%; Salt mixture, 4.3%; Butter fat, 5.0%.	This ration produced good growth in rats.	McCollum and Davis.[94]
133	Cooked in double boiler 4 hours.	Wheat embryo of the above ration.	Growth was as good on this as previous ration.	do.

The Effect of Heat on Vitamin B in Seeds—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
134	Heated 1 hour at 250° F.	The wheat embryo in the above ration.	Growth was undiminished.	do.
135	Unheated.	Pearl barley.	Two pigeons died of polyneuritis respectively in 53 and 60 days.	Weill and Mouriquand.[95]
136	Heated ½ hour at 248° F.	do.	Two pigeons died respectively in 38 and 43 days.	do.
137	Unheated.	Polished rice.	Two pigeons died in 22 and 25 days respectively.	do.
138	Heated 1½ hours at 248° F.	do.	Two pigeons succumbed respectively in 11 and 16 days.	do.
139	Heated ½ hour at 248° F.	Barley.	One pigeon succumbed in 35 days, cured by 130 grams raw barley; one succumbed in 34 days, died in 38 days.	do.
140	Unheated.	Wheat embryo.	Minimum amount to cure 300 to 400 gram pigeon of polyneuritis was 1.0 to 2.5 grams.	Chick and Hume.[23] [60]
141	Heated 2 hours between 208° to 217° F.	do.	Minimum amount to cure 300 to 400 gram pigeon of polyneuritis was 2.5 grams.	do.
142	Heated 40 minutes between 212° to 243° F.	do.	Minimum amount to cure 300 to 400 gram pigeon of polyneuritis was 5.0 grams.	do.
143	Heated 2 hours between 244° to 255° F.	do.	No cure from 10.0 grams.	do.
144	Unheated.	Alcoholic extract of peas.	Extract of 40 grams effected cure of polyneuritis.	do.
145	Unheated.	Alcoholic extract of kilned pea flour.	Extract of 80 grams gave little improvement but no cure.	do.
146	Heated 2 hours at 212° F.	Wheat embryo.	No loss in curative value for polyneuritis in fowls.	Chick and Hume.[87]
147	Heated 40 minutes at 235° F.	do.	For fowl ½ of Vitamin B was lost.	do.
148	Heated 2 hours at 244° to 255° F.	Wheat embryo.	For fowl ¾ or more of Vitamin B was lost.	do.

The Effect of Heat on Vitamin B in Seeds—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
149	Heated 1¼ hours at 248° F.	Navy beans.	No loss in Vitamin B for rat growth indicated.	McCollum, Simmons and Pitz.[96]
150	Heated 20 minutes at 248° F.	Soy Bean flour.	No loss in Vitamin B for rat growth indicated.	Cohen and Mendel.[97]
151	Heated 20 minutes at 248° F.	Navy beans.	Fifty per cent in rats' diet supplied Vitamin B.	Daniels and McClurg[59]
152	Heated 40 minutes at 248° F.	Soy beans.	Fifty per cent in rats' diet supplied Vitamin B.	do.
153	Heated 20 minutes at 248° F.	Extract of heated navy beans.	Equivalent of 50 per cent in diet supplied Vitamin B for rats.	do.
154	Heated 40 minutes at 248° F.	Extract of heated soy beans.	Equivalent of 55 per cent in diet supplied Vitamin B for rats.	do.
155	Heated 40 minutes at 216° to 225° F.	Wheat embryo.	Slight loss in antipolyneuritic value for fowl.	Chick and Hume.[98]
156	Unheated.	Extract from umilled rice.	Cured polyneuritis in pigeons, stimulated rat and yeast growth.	Emmet and Stockholm.[99]
157	Heated 1 hour at 248° F.	Extract from heated rice.	Cured polyneuritis in pigeons, stimulated rat and yeast growth as much as extract from unheated rice.	do.
158	Heated 2 hours at 248° F.	do.	No longer cured polyneuritis or stimulated rat growth to same extent as above. Yeast growth stimulant undiminished.	do.
159	Heated 6 hours at 248° F.	do.	Rat growth became still less but yeast growth was undiminished.	do.
160	Heated 1 hour at 248° F.	Unmilled rice.	Cured polyneuritis in pigeons and stimulated rat growth as well as unheated rice.	Emmet and Luros.[87]
161	Heated 2 hours also 6 hours at 248° F.	do.	No longer cured polyneuritis in pigeons but stimulated rat growth.	do.
162	Heated 2½ hours at 248° F.	Corn, kaffir corn, barley, split peas.	The antineuritic vitamin was destroyed and these could be used as polyneuritic rations for pigeons.	Davis.[100]

Effect of Heat on Vitamin B in Seeds—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
163	Heated ½ hour at 248° F.	Navy beans.	For yeast there was 40.6 per cent loss of Vitamin B.	Miller.[101]
164	Heated 1½ hours at 212° F.	Navy beans.	No loss of Vitamin B for yeast.	do.
165	Heated 1½ hours at 248° F. in oven.	Grains.	Has no injurious effect on Vitamin B.	Nitzescu.[231]
166	Heated 1 hour at 230° F. in autoclave.	do.	Destroys Vitamin B.	do.

The Effect of Heat on Vitamin B in Meat and Eggs.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
167	Unheated.	Potato flour with a little raw meat.	Two hens receiving it remained normal.	Eijkman.[91]
168	Heated 2 hours at 257° F.	Potato flour with a little raw meat.	Two hens showed symptoms of polyneuritis in 21 days.	do.
169	Unheated.	Horse meat.	Two hens died respectively in 2 and 4 months with no symptoms of polyneuritis.	do.
170	Heated 2 hours at 248° F.	do.	Of three hens, 1 died in 1 month, 1 in 4 months, but not of polyneuritis; and 1 was normal after 4 months.	do.
171	Heated several days at 212° F.	Buffalo meat.	Total loss of antipolyneuritic effect toward fowl.	Grijns.[92]
172	Heated 1 to 3 hours at 248° to 266° F.	Horse meat.	Total loss of Vitamin B for dogs.	Schaumann.[102]
173	Heated 4 minutes at 212° F.	Egg yolk.	No loss in antineuritic property for fowls.	Cooper.[103]
174	Boiled ½ hour.	Meat (minced).	No symptoms of polyneuritis when fed to fowls.	Holst.[93]
175	Boiled ½ hour then heated ½ hour at 230° F.	Meat (minced.)	One chicken developed polyneuritis, the other degeneration of nerves.	do.
176	Boiled ½ hour then heated 1 hour at 248° F.	do.	Chickens developed symptoms of polyneuritis.	do.

The Effect of Heat on Vitamin B in Meat and Eggs—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
177	Heated 1½ hours at 248° F.	Beef.	Cats succumbed to polyneuritis in 35 days.	Weill and Mouriquand.[96]
178	Heated 3 hours at 248° F.	do.	This meat was still a fairly satisfactory food for cats and dogs. The antineuritic vitamin was somewhat reduced but cats did not develop polyneuritis.	Voegtlin and Lake.[104]
179	Unheated.	Alcoholic extract of raw beef.	Equivalent of 140 grams meat or 30 grams dry weight required to cure pigeon of polyneuritis.	Chick and Hume.[66]
180	Unheated.	Alcoholic extract of Maconochie ration (British army).	Equivalent of 440 grams meat or 106 grams dry substance required to cure pigeon of polyneuritis.	do.
181	Unheated.	Alcoholic extract of new ration (British army), tinned roast beef.	Equivalent of 350 grams meat or 112 grams dry weight required to cure pigeon of polyneuritis.	do.
182	Heated ½ hour at 248° F. (with the view to destroy all vitamin B).	Meat and eggs.	Fowls on this diet developed polyneuritis. If fed polished rice with it the disease was delayed or did not appear at all, showing other substances than Vitamin B are involved in polyneuritis.	Vedder.[105]

The Effect of Heat on Vitamin B in Milk.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
183	Heated 2 minutes at 212° F.	Protein free milk.	No apparent loss of Vitamin B for rats.	Osborn and Mendel.[106]
184	Unheated.	Polished rice 77% Milk powder 15% Salt mixture 3% Butter-fat 5%.	This ration produced normal growth and reproduction in rats.	McCollum and Davis.[94]

Effect of Heat on Vitamin B in Milk—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
185	Cooked in double boiler 4 hours.	The milk powder in the above ration.	With the milk powder cooked the growth was nearly as good.	McCullum and Davis.[94]
186	Heated 1 hour at 250° F.	The milk powder of the above ration.	Practically no growth was obtained in rats when the milk powder in the above ration was given this cooking.	do.
187	Boiled 6 hours.	Whey which was 15 per cent of rats' ration and source of Vitamin B.	Produced good growth in rats.	do.
188	Heated 1 hour at 250° F.	Evaporated whey.	There was no loss indicated when this was 10 to 16 per cent of rats' ration and source of Vitamin B.	do.
189	Unheated.	Fresh milk.	One hundred cc.+40 grams polished rice were fed to three fowl. Two developed polynuritis in 31 days; one developed polyneuritis in 86 days. All gained weight.	Gibson and Conception.[86]
190	Heated 2 hours at 257° F.	do.	One hundred cc.+40 grams polished rice were fed to three fowl. One developed polyneuritis in 31 days; 1 developed polyneuritis in 62 days; 1 died 36th day, cause unknown. All gained in weight as on fresh milk.	do.
191	Unheated.	do.	Two hundred cc.+10 to 20 grams polished rice were fed daily per fowl. None developed polyneuritis.	do.
192	Heated 2 hours at 257° F.	do.	Two-hundred cc.+10 to 20 grams polished rice were fed daily to fowls. None developed polyneuritis.	do.

Effect of Heat on Vitamin B in Milk—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
193	Raw or heated 2 hours at 257° F.	Fresh milk.	Constituting the entire diet of young dogs and pigs, raw or autoclaved fresh milk were alike inadequate and symptoms of beriberi were induced.	Gibson and Conception.[36]
194	Boiled several hours.	Protein free milk.	Vitamin B was not destroyed.	Osborne and Mendel.[107]
195	Boiled 1, 10 and 45 minutes.	Fresh milk.	Rats grew slowly and did not reproduce.	Daniels and Stuessy.[108]
196	Heated 45 minutes at 237° F.	do.	Rats grew nearly as well as those on boiled milk at first but declined rapidly later.	do.
197	Heated 2 hours also 6 hours at 248° F.	Fullers earth activated with protein free milk.	No longer cured polyneuritis in pigeons but stimulated rat growth.	Emmet and Luros.[57]
198	Heated 2 hours also 6 hours at 248° F. dry heat.	The above activated fuller's earth.	Properties for curing polyneuritis in pigeons partially lost.	do.
199	Heated quickly to boiling, boiled 1 minute.	Milk.	Rats grew normally and reproduced.	Daniels and Laughlin.[109]
200	Brought to boiling in 35 minutes, boiled 1 minute.	do.	Rats grew only half normal rate and did not reproduce.	do.
201	Heated 30 to 45 minutes at 149° to 180° F.	do.	Rats grew poorly. Addition of tricalcium phosphate or calcium glycerophosphate made it equivalent to milk brought rapidly to boiling and boiled one minute in making growth and reproduction normal.	do.
202	Commercial brand.	Sweetened condensed milk.	Produced normal growth in rats.	do.
203	Three commercial brands.	Evaporated milk.	All rats failed to grow and died in a few weeks.	do.

Effect of Heat on Vitamin B in Milk—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
204	Commercial brand.	Same evaporated milk as above thickened with starch or with added calcium glycerophosphate, or tricalcium phosphate.	Rats grew normally. Authors believe starch paste held calcium phosphate from settling out and rats ate it with the milk.	Daniels and Laughlin.[109]
205	Commercially canned.	Evaporated and sweetened condensed milk.	The Vitamin B is retained in almost the original amount.	Rosenau.[110]
206	Heated at 212° F. for 6, 12, 24 or 48 hours.	Skim milk powder.	Vitamin B as determined by rat growth was not affected.	Sherman and Spohn.[232]
207	Heated at 212° F. for 12 to 48 hours.	do.	Did not lose its ability to stimulate yeast growth.	Sherman and Edgeworth.[233]
208	Pasteurized by the "hold process."	Milk.	Babies frequently did not grow well.	Daniels and Stearns.[234]
209	Pasteurized by rapidly heating to boiling "flash method."	do.	Babies changed to this began to grow.	do.

The Effect of Heat on Vitamin B in Vegetables and Fruits.

210	Heated 15 minutes at 248° F. or boiled until tender.	Cabbage.	Vitamin B was supplied for rats when 250 grams were added to 100 grams dry ration.	Daniels and McClurg.[58]
211	Boiled 10 min. in covered vessel with least possible water.	Togi.	One gm. of raw togi daily did not protect guinea pig from scurvy; 5 gms. did. After boiling 5 gms. gave no better results than 1 gm. raw.	Santos.[242]

Effect of Heat on Vitamin B in Vegetables and Fruits—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
212	Boiled 30 to 40 minutes or canned by cold-pack method (blanch 5 minutes, process 2 hours under boiling water in glass jars.)	Carrots.	Fifty per cent in rats' ration supplied sufficient vitamin B.	Denton and Kohman.[111]
213	Comminuted and boiled until very tender.	Carrots, turnips, celery.	The soup from these greatly stimulated growth in infants 1½ to 5 months old fed on modified milk.	Daniels, Byfield and Laughlin.[29]
214	Heated at 140° to 158° F. until dry.	Canned tomatoes.	Rich in Vitamin B. One to 1½ grams daily per rat supplied Vitamin B in sufficient amount.	Osborne and Mendel.[112]
215	Heated ½ hour at 212° F.	Carrots.	No loss in Vitamin B for yeast.	Miller.[101]
216	Processed 45 minutes at 239° F.	Carrots (diced) canned in pint jars.	No loss in Vitamin B for yeast.	do.
217	Heated ½ to 1 hour at 212° F.	Cabbage.	No loss of Vitamin B for yeast.	Whipple.[113]
218	Boiled.	Onion.	No loss of Vitamin B for yeast.	do.
219	Boiled 5 minutes.	Tomato juice strained from canned tomatoes stored 1 year.	Five cc. daily per pigeon cured polyneuritis.	Hess and Unger.[44]
220	Heated 4 hrs. at 212°, 230°, 248° and 268° F.	Canned tomato juice strained and filtered.	Lost respectively 20, 33, 47, and 55 per cent of its Vitamin B.	Sherman and Grose.[236]
221	Raw and canned, the latter without the juice.	Pineapple.	Gave equal growth curves when 5 grams daily supplied Vitamin B for rats. Ten grams daily gave very little better growth curves, although author states that the canned pineapple had less Vitamin B than the raw.	Miller.[212]

Effect of Heat on Vitamin B in Vegetables and Fruits—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
222	Raw, home and pressure cooked, canned and dried.	Spinach.	Fed as source of both Vitamins A and B, with basal ration free from both, thus making results inconclusive. Also water content of canned spinach was ignored.	Stanley and Stillman.[213]
223	Raw, home, cooked and canned by blanching 1 to 5 min. and processing 70 to 120 min. at 240° F.	do.	After canned spinach was reduced to dryness to decrease bulk before feeding the rats inclined not to eat as much as of the raw or home cooked. Actual destruction of Vitamin B could not be demonstrated.	Eddy, Kohman and Carlsson.[211]

Effect of Drying on Vitamin B.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
224	Dried and stored 2 years.	Yeast.	Cured polyneuritis in pigeons as well as fresh yeast.	Cooper.[114]
225	Heated several hours at 194° F. until dry.	Pig's heart, Pig's liver, Pig's kidney, Pig's brain.	Sufficient Vitamin B supplied by 19, 22, 22 and 32.5 per cent respectively in rats' diet. Loss not indicated.	Osborne and Mendel.[115]
226	Heated at 221° F. in current of air until dry.	Baker's yeast.	No loss in Vitamin B.	Hawk, Fishback and Berguin.[89]
227	Heated at 140° to 158° F. until dry.	Canned tomatoes.	Rich in Vitamin B, 1.0 to 1½ grams daily per rat supplied Vitamin B in sufficient amount.	Osborne and Mendel.[112]
228	do.	Spinach, Cabbage, Turnips, Carrots,	Not quite as rich as canned tomato in Vitamin B.	do.
229	do.	Beets, Potatoes.	Not as rich as the above vegetables in Vitamin B.	do.
230	do.	Alfalfa, Clover, Timothy.	About comparable to spinach in Vitamin B.	do.

Effect of Drying on Vitamin B—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
231	Scalded or steamed few minutes then sun-dried, then boiled 30 minutes and drained.	Carrots, Brinjal, Spinach, Turnips, Turnip-tops.	Ten grams dry weight daily fed with polished rice prevented polyneuritis in fowls.	Shorten and Roy.[116]
232	Dried by spray process.	Skim milk.	Powder from 75 cc. milk daily per pigeon on polished rice diet protected from polyneuritis. Drying did not lower growth promoting power for rats.	Johnson and Hooper.[117]
233	Commercially dried.	Milk.	Retained Vitamin B in almost original amount.	Rosenau.[110]
234	Dried at 226° F. for 72 hours.	Yeast.	Does not lose its vitamin.	Karr.[230]
235	Spray, dried.	Milk.	Vitamin B not injured.	Johnston.[236]
236	Desiccation by suitable means.	Orange.	Vitamin B may be conserved.	Osborne and Mendel.[217]
237	Dried.	Thompson seedless, loose muscat or seeded muscat raisins.	Contain Vitamin B.	Dutcher and Outhouse.[218]
238	Dried for 16 to 18 hours at 115° to 160° F.	Pumpkin.	Vitamin B not appreciable diminished.	Morgan and Francis.[221]
239	Dried quickly at 140° F.	Radishes.	As rich in Vitamin B as similar amount of milk solids or orange juice solids.	Morgan.[237]

The Effect of Acid and Alkali on Vitamin B.

240	Heated 1 hour at 212° F.	Bran in 0.5 per cent hydrochloric acid.	The antineuritic properties were not destroyed.	Shiga and Kusama.[119]
241	Heated 1 hour at 260° F.	do.	The antineuritic properties were lost.	
242	Untreated.	Extract from 2 kilograms rice polishings.	Had no effect in curing fowl of polyneuritis.	Vedder and Williams.[120]

The Effect of Acid and Alkali on Vitamin B—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
243	Treated with 5 per cent hydrochloric or sulfuric acid.	Extract from 100 grams rice polishings.	Cured fowl of polyneuritis.	Vedder and Williams.[120]
244	Acid hydrolysis.	Concentrate from alcoholic extract of rice polishings.	Cured polyneuritis in fowl more promptly than before the acid treatment.	Williams and Seidell.[121]
245	Heated 5 hours at 194° F.	Extract from wheat bran and cow peas in 5 to 10 per cent sulfuric acid.	Vitamin B was not destroyed by this treatment.	Sullivan and Voegtlin.[122]
246	Baked.	Whole corn meal bread baked with sodium carbonate.	Lost its antineuritic properties.	Voegtlin, Sullivan and Myers.[123]
247	Heated at 208° F.	Extract of egg yolk containing Vitamin B in concentrated hydrochloric acid.	Vitamin B was not destroyed.	Steenbock.[124]
248	Room temperature.	Extract of egg yolk containing Vitamin B in concentrated sodium hydroxide.	Vitamin B was not destroyed.	do.

The Effect of Acid and Alkali on Vitamin B—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
249	Boiled	Extract of egg yolk containing Vitamin B in concentrated alkali.	Vitamin B was destroyed.	Steenbock.[124]
250	Heated 3 hours at 248° F.	Beef ground with sodium carbonate solution until strongly alkaline to litmus.	Cats and dogs very quickly developed polyneuritis. Six rats lived more than three months and all grew. One lived 7 months and gained 150 grams. This showed not all Vitamin B was destroyed for rats.	Voegtlin and Lake.[104]
251	Boiled 24 hours.	Yeast, in 20 per cent sulfuric acid.	Still cured polyneuritis in pigeons.	Cooper and Funk.[125]
252	Room temperature 24 hours.	Yeast extract with 5 per cent sodium hydroxide.	Very little loss in Vitamin B for rats.	Drummond.[88]
253	Heated 5 hours at 212° F.	Yeast extract with 5 per cent sodium hydroxide.	Most of Vitamin B destroyed for rats.	do.
254	Cooked 1½ hours.	Navy Beans 50 grams in 33 cc. 5 per cent sodium bicarbonate.	Sufficient Vitamin B supplied by 50 per cent in rats' diet.	Daniels and McClurg.[88]
255	Cooked 2 hours.	Soy Beans 50 grams in 33 cc. 5 per cent sodium bicarbonate.	Sufficient Vitamin B supplied by 55 per cent in rats' diet.	do.

The Effect of Acid and Alkali on Vitamin B—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
256	Cooked ¾ hour.	Cabbage, 250 grams in 63 cc. .5 per cent sodium bicarbonate.	Vitamin B supplied by 250 grams per 100 gram dry ration for rats.	Daniels and McClurg.[58]
257	Heated ½ hour at 212° F.	Extract of Navy Beans heated at 248°F. for 20 min., plus 6.4 cc. excess tenth normal sodium hydroxide.	Equivalent of 50 per cent in diet supplied sufficient Vitamin B for rats.	do.
258	Heated ½ hour, also 1 hour at at 212° F.	Extract of Soy Beans heated at 248°F. for 40 minutes, plus 6.4 cc. excess tenth normal sodium hydroxide.	Equivalent of 55 per cent in diet supplied sufficient Vitamin B for rats.	do.
259	Evaporating to dryness with nitrous or hydrochloric acid.	Wheat embryo extract.	Did not effect rat growth stimulant.	McCollum and Simmons.[126]
260	Evaporating to dryness with 0.28 per cent sodium hydroxide.	Wheat embryo extract.	Stimulating effect on rat growth completely destroyed.	do.
261	At room temperature for 21½ hours then 2 hours on boiling water bath.	Yeast in 10 times its weight of tenth normal sodium hydroxide.	No loss in rat growth promoting power.	Osborne, Wakeman and Ferry.[171]

The Effect of Acid and Alkali on Vitamin B—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
262	Soaked 3 hours then heated 3 hours at 250° F.	Oats in 2 per cent sodium bicarbonate.	Forty per cent in rats' diet no longer supplied Vitamin B in sufficient amount as did the unheated oats, but yeast growth stimulating power was undiminished.	Souze and McCollum.[127]
263	Unheated.	Wheat germ.	Three per cent in rats' ration produced normal growth.	do.
264	Soaked 3 hours then heated 3 hours at 250° F.	Same in 2 and 4 per cent sodium bicarbonate.	Fifteen per cent in rats' ration produced no growth but yeast growth stimulant was undiminished.	do.
265	Soaked 3 hours then heated 3 hours at 250° F.	Ground beef in 2 per cent sodium bicarbonate.	Yeast growth stimulant was undiminished.	do.
266	Boiled 5 minutes.	Orange juice with an excess of 2 per cent sodium hydroxide.	Rats grew as well as with untreated juice. The authors assumed that C was destroyed and regarded these results as proof that rats required no Vitamin C. See Table 3.	Byfield, Daniels and Laughlin.[128]
267	Heated ½ to 18 hours at 68° F.	Yeast extract in tenth normal sodium hydroxide.	No loss in Vitamin B for rats.	Osborne and Leavenworth.[129]
268	Heated 90 hours at 68° F.	Yeast extract in tenth normal sodium hydroxide..	Considerable loss of Vitamin B for rats.	do.
269	Heated 18 hours at 68° F. then 1 hour at 194° F.	Yeast extract in tenth normal sodium hydroxide.	Considerable loss of Vitamin B for rats.	do.

The Effect of Acid and Alkali on Vitamin B—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
270	Heated 1⅙ hours at 212° F.	Navy beans in 0.5 per cent sodium bicarbonate.	For yeast there was 37.5 per cent loss of Vitamin B.	Miller.[101]
271	Heated ½ to 1 hour at 212° F.	Cabbage in 0.1 per cent sodium bicarbonate.	No loss of Vitamin B for yeast.	Whipple.[113]
272	Heated ½ to 1 hour at 212° F.	Cabbage in 5 per cent vinegar.	No loss of Vitamin B for yeast.	do.
273	Boiled 1 hour.	Alfalfa and wheat embryo extracts in 5 per cent sodium hydroxide.	No loss of Vitamin B for yeast.	Fulmer, Nelson and Sherwood.[14]

Vitamin B, Miscellaneous.

274	Stored 3 years. Moldy and worm-eaten.	Unmilled rice.	Antineuritic properties were entirely lost.	Shiga and Kusama.[119]
275	Ordinary process.	Puree of peas.	Cured human beri-beri but when made from peas three years old, it was entirely inactive.	Funk.[120]
276	Ultra-violet rays 8 hours.	Autolyzed yeast extract.	No loss in antineuritic property for pigeons or growth stimulating properties for rats.	Zilva.[69]
277	Heated ½ hour at 140° F.	Hemophilic nutrient mediums (many tissue extracts.)	Supplied accessory growth factor for the Influenza Bacillus.	Davis.[121]
278	Heated 2½ hours at 140° F.	Blood-agar, serum, milk.	Supplied accessory growth factor for the meningococcus.	Lloyd.[122]
279	Heated 15 minutes at 194° F.	Physiological salt solution of blood serum.	Lost part of its growth-stimulating effect for the Influenza Bacillus.	Agulhon and Legroux.[123]
280	Heated at 212° F. Time unknown.	Same in gelatin.	Lost part of its growth-stimulating effect for the Influenza Bacillus.	do.

Vitamin B, Miscellaneous—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
281	Heated at 230° F. Time unknown.	Same in gelatin.	More loss of growth-stimulating effect.	Agulhon and Legroux.[133]
282	Heated at 248° F. Time unknown.	Same in gelatin.	Total loss of growth-stimulating effect.	do.
283	Heated ½ hour at 273° F.	An extract of bacterized peat.	Auximone or plant growth stimulant and actobacter chroococcum growth undiminished.	Bottomley.[134]
284	Stored eight years.	Fuller's earth extract of Vitamin B	No loss in activity.	Seidell.[118]
285	Ozone.	Autolyzed yeast.	Did not destroy Vitamin B.	Zilva.[208]
286	Stored 38 years by hanging in bags.	Samples of peas and lentils.	Appeared to have lost a small amount of their Vitamin B compared with fresh lentils.	Findley.[228]
287	Stored 100 years in the husk.	Rice.	No loss of antineuritic properties.	Jansen.[239]
288	Enough formaldehyde added to prevent souring 48 hours at room temperature.	Milk.	Growth curves with chicks same as with untreated milk.	Bleile and Seymour.[228]
289	Fresh, stored 2 years and in case of pork 9 years.	Beef, mutton, lamb and pork.	Storage has no effect on Vitamin B.	Wright.[240]
290	Commercial and home made.	Orange and lemon marmalades and candied lemonpeel.	Commercial products appreciably lower in Vitamin B than home made items but fed on equal weight basis irrespective of sugar content.	Morgan and Chaney.[209]

TABLE 3.—THE STABILITY OF VITAMIN C.

The Effect of Heat on Vitamin C in Fruits.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
291	Heated ¾ hour at 230° F.	Orange juice.	Three cc. daily per guinea pig protected against scurvy, but growth was not as good as upon raw juice.	Hess and Unger.[135]
292	Boiled, then neutralized.	do.	Given intravenously it cured guinea pigs of scurvy.	do.
293	Boiled 10 minutes.	do.	Unharmed as antiscorbutic for guinea pigs.	Hess an Unger.[21]
294	Heated 1 hour at 212° F. and also 1 hour at 250° F.	Raspberries and cloudberries.	Antiscorbutic qualities but little injured at 212° or even at 230°. Cloudberries retained antiscorbutic properties for at least 3 months after cooking.	Holst an Frolich.[6,15]
295	Heated 1 hour at 158° F.	Orange juice.	Guinea pig was protected practically as well by 1.5 cc. daily as by unheated juice.	Delf.[136]
296	Heated 1 hour at 212° F.	do.	Guinea pig was protected against scurvy by 1.5 to 3.0 cc.	do.
297	Heated 1 hour at 266° F.	do.	Guinea pig was protected against scurvy by 2.0 to 3.0 cc.	do.
298	Neutralized, then heated 1 hour at 212° F.	do.	Guinea pig was protected against scurvy by 1.5 to 3.0 cc. The neutralization produced no effect on the stability.	do.
299	Canned and processed 20 to 30 minutes at 176° to 212° F. Not more than 5 minutes at 212° F. Stored 3 months.	Oranges canned with water.	Equivalent of 1.5 cc. juice protected guinea pig against scurvy. This amount of raw juice was minimum found necessary.	do.
300	Heated 5 minutes at 212° F.	Lemon juice.	Antiscorbutic value not appreciably affected.	Bassett-Smith.[137]
301	Heated ¾ hour at 136° F.	do.	Antiscorbutic value appreciably reduced.	do.
302	Raw.	Orange juice.	Three cc. daily per guinea pig supplied sufficient Vitamin C for good growth.	Dutcher, Harshaw and Hall.

Effect of Heat on Vitamin C in Fruits—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
303	Heated ½ hour at 145° F. in closed vessel.	Orange juice.	Three cc. daily per guinea pig supplied sufficient Vitamin C for good growth.	Dutcher, Harshaw and Hall.[7]
304	Boiled ½ hour.	do.	Three cc. daily per guinea pig as satisfactory as raw juice.	do.
305	Untreated.	Raw apples and bananas.	Ten grams daily protected a guinea pig against survy for three months.	Givens, McCluggage and Van Horn.[138]
306	Heated ¼ hour at 212° F.	Cooked apples and bananas.	Ten grams weighed fresh was no longer able to protect guinea pigs against scurvy.	do.
307	Dried at 131° to 140° F., or at 95-104°F. then cooked ¼ hour at 212° F.	Apples and bananas.	Ten grams daily weighed fresh did not protect guinea pigs against scurvy.	do.
308	Boiled 15 minutes.	Rhubarb juice.	Guinea pigs were cured of scurvy by it.	Pierson and Dutcher.[139]
309	Neutralized and heated.	Orange or lemon juice.	Only effective as antiscorbutic in fresh state. Heating damages Vitamin C but does not destroy it entirely.	Vedder.[222]
310	Raw.	Strawberry juice.	Ten cc. daily cured guinea pigs of scurvy in seven days.	Smith, Bergheim and Hawk.[241]
311	Boiled 5 minutes.	do.	do.	do.
312	Raw fresh.	English tomatoes.	Daily requirement of guinea pig as antiscorbutic, 2 cc.	Delf.[243]
313	Bottledandstored 4–6 months.	do.	do. 7.5 cc.	do.
314	Canned whole but not stored.	do.	do. 8.5 cc.	do.
315	Canned whole and stored 3¾ to 4 years.	do.	do. 10 cc.	do.
316	Puree canned.	do.	do. 15cc.	do.

Effect of Heat on Vitamin C in Fruits—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
317	Raw apples, apple sauce, baked apples and apples commercially canned by various methods and processed 5, 10 and 30 min.	Apples.	Apple-sauce and baked apples lost all Vitamin C. Canned "nitrogen-filled" apples lost most of Vitamin C. No loss of Vitamin C in apples canned by respiratory-"soaking"-process. Cold storage of raw apples reduced the content of Vitamin C, but storage of canned apples at ordinary temperature did not.	Kohman, Eddy, and Carlsson.[194]

The Effect of Heat on Vitamin C in Milk.

318	Unheated.	Milk.	Prevented scurvy in guinea pigs receiving oats.	**Frölich.[140]**
319	Pasteurized.	do.	Did not prevent scurvy in guinea pigs fed on oats.	**do.**
320	Heated 20 minutes at 165° F.	do.	Outbreak of scurvy among children in hospital in 1912.	**Hess.[141]**
321	Heated ½ hour at 145° F.	do.	Similar outbreak in 1913.	**do.**
322	Heated ½ hour at 165° F. Pasteurized commercially.	do.	Outbreak of scurvy among children in hospital.	**Hess.[142]**
323	Heated ½ hour at 145°F. Pasteurized in laboratory.	do.	Of 6 infants fed upon it, none developed survy. One child was cured of scurvy by changing to this milk.	**do.**
324	Pasteurized as above, then held 24 hours on ice.	Same milk as in previous experiment.	Out of eight infants fed upon it, two developed scurvy.	**do.**
325	Pasteurized by heating to boiling or higher in hermetically sealed bottles.	Milk.	Children's specialists in France have reported thousands of babies fed on hundreds of thousands of bottles of this milk over a course of years with not a case of scurvy.	**Hess.[144]**

Effect of Heat on Vitamin C in Milk—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
326	Unheated.	do.	Forty-five cc. daily per guinea pig prevented scurvy.	Hart, Steenbock and Smith.[142]
327	Heated 10 minutes at 248° F.	do.	One-hundred cc. daily per guinea pig allowed, 45 cc. consumed. Did not prevent scurvy.	do.
328	Commercially canned.	Evaporated milk.	Had no antiscorbutic value for guinea pigs.	do.
329	Commercially canned.	Condensed milk.	Eight ounces per day cured and prevented scurvy among children in war zone.	Alonzo Taylor.[143]
330	Untreated.	Milk, fresh from model dairy.	One hundred to 150 cc. daily for 300 to 400 gram guinea pig or 2 to 3 kilogram monkey prevented scurvy.	Barnes and Hume.[45]
331	Heated 5½ minutes at 158° to 212° F.	Same milk as above scalded.	Less antiscorbutic than raw but more than powdered.	do.
332	Commercially canned.	Sweetened condensed milk.	May retain much of its antiscorbutic vitamin and be able to cure infantile scurvy.	Hess.[144]
333	Commercially canned, stored 2 to 4 months.	Sweetened condensed milk.	No loss of vitamin evident from feeding monkeys.	Hume.[145]
334	Heated 40 min. at 140° F. in glass and in copper.	Milk.	Guinea pigs did not succumb to scurvy when milk was heated in glass but died of scurvy in 4 weeks when milk was heated in copper.	Hess and Unger.[244]
335	Pasteurized with 2.5, 6.0 and 9.0 mg. copper per l.	Milk.	Vitamin C appreciably reduced in all cases.	Hess and Weinstock.[245]
336	Prepared below 176° F. in absence of oxygen.	Sweetened condensed milk.	Contains the antiscorbutic factor and can retain it for 15 months.	Lesne and Vagliano.[246]
337	Air bubbled through at 14.5° for 30 minutes.	Milk.	Lost some of its Vitamin C.	Anderson, Dutcher, Eckles and Wilbur.[247]

The Effect of Heat on Vitamin C in Milk—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
338	Pasteurized while oxygen was bubbled thru or with added hydrogen peroxide.	Milk.	Lost its vitamin rapidly.	Anderson, Dutcher, Eckles and Wilbur.[247]
339	Boiled.	do.	Practically equal in nutritive value to raw.	do.
340	Pasteurized at 145° F. for 30 minutes while being stirred rather violently.	do.	Produced scurvy very quickly.	do.
341	Pasteurized in closed vessels.	do.	Apparently does not lose its Vitamin C.	do.
342	Pasteurized while bubbling carbon dioxide through.	do.	do.	do.
343	Boiling 30 minutes.	Orange juice.	Apparently loses no Vitamin C.	do.

The Effect of Heat on Vitamin C in Cabbage.

344	Unheated.	Cabbage.	Thirty grams daily with wheat bread caused guinea pigs to thrive.	Holst and Frolich.[6]
345	Heated ½ hour at 212° F.	do.	Thirty grams daily with wheat bread caused guinea pigs to thrive.	do.
346	Heated ½ hour at 230° F.	do.	Three guinea pigs receiving 30 grams daily with wheat bread died of scurvy.	do.
347	Raw.	do.	One and one-half grams daily per guinea pig fed on oats protected against scurvy.	Holst and Frolich.[159]
348	Heated 1 hour at 212° F.	Cabbage in ½ per cent salt solution.	Of 5 guinea pigs receiving 30 grams with oats daily, all were protected against scurvy except one.	do.
349	Steamed ½ hour at 230° F.	Cabbage	Thirty grams daily with white bread delayed scurvy in 3 guinea pigs but all succumbed finally.	do.

Effect of Heat on Vitamin C in Cabbage—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
350	Steamed ½ hour at 248° F.	Cabbage.	Three guinea pigs, receiving 30 grams each daily succumbed quickly to scurvy.	Holst and Frolich.[159]
351	Heated 1 hour at at 212° F.	do.	Three guinea pigs receiving 30 grams daily each and 3 receiving 15 grams each daily remained normal 90 days.	Delf.[1]
352	Heated 2 hours at 212° F.	do.	Five guinea pigs receiving 15 grams each daily remained normal 90 days.	do.
353	Heated 1 hour at 230° F.	do.	Five guinea pigs receiving 15 grams each daily manifested slight symptoms after 85 to 112 days.	do.
354	Heated 1 hour at 248° F.	do.	Four guinea pigs receiving 15 grams each daily showed slight symptoms after 90 days.	do.
355	Heated 2 hours at 248° F.	do.	Four guinea pigs receiving 15 grams each daily all manifested symptoms after 18 to 26 days, but they were slight and the animals lived until end of experiment, *i. e.*, 90 days.	do.
356	Heated 1 hour at 266° F.	do.	Four pigs receiving 15 grams each daily all had symptoms after 15 to 28 days but only slight, and animals lived until end of experiment, *i. e.*, 90 days.	do.
357	Heated 2 hours at 266° F.	do.	Four guinea pigs receiving 15 grams each daily had definite symptoms of scurvy, but remained alive until end of experiment, *i. e.*, 86 days.	do.

Effect of Heat on Vitamin C in Cabbage—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
358	Blanched 3 minutes in dilute sodium bicarbonate packed in enameled cans filled with boiling water, closed and processed in boiling water 1½ hours. Temperature in center of can was between 194° F. and 212° F. for 1 hour.	Cabbage.	The drained cabbage was fed and had lost 70 per cent of the antiscorbutic value for guinea pigs, *i. e.*, the drained cabbage retained only 30 per cent. 15 grams, drained, daily per guinea pig supplied sufficient antiscorbutic but not sufficient A for growth unless the liquor was also fed. Liquor was 39 per cent of contents of can.	Campbell and Chick.[146]
359	Raw.	Cabbage juice, green or white.	One to 1.5 cc. daily per guinea pig protected against scurvy.	Delf.[136]
360	Heated 1 hour at 212° F.	do.	Seven and one-half to 10 cc. protected against scurvy.	do.
361	Heated 20 min. at 212° F.	do.	Seven and one-half to 10 cc. protected. No difference between 20 minutes and 1 hour heating indicated.	do.
362	Open kettle cooked and pressure cooked'	Cabbage.	Twenty grams daily required as antiscorbutic for guinea pig as against 1 gram raw.	Eddy, Shelow, Pease, Richter and Watkins.[248]
363	Canned and processed 30 min. at 212°, 240° and 260° F.	do.	Four to 5 grams daily required as antiscorbutic for guinea pig against 1 gram raw and 20 grams home-cooked.	Eddy and Kohman.[249]

The Effect of Heat on Vitamin C in Other Vegetables

364	Steamed ½ hour at 212° F.	Potato.	Seventeen to 20 grams as effective antiscorbutic for guinea pigs as 1.5 to 3.0 cc. orange juice.	Chick and Rhodes.[147]
365	Heated ¼ hour at 212° F.	Cabbage and sprouted lentils in 0.5%citric acid.	More destruction of antiscorbutic vitamin than when boiled in water.	Delf.[1]

Effect of Heat on Vitamin C in Other Vegetables—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
366	Boiled.	Potato.	One tablespoonful more effective as antiscorbutic than one-half banana.	Hess and Unger.[21]
367	Cooked ¾ hour.	Old carrots.	Thirty-five grams daily per guinea pig on hay oats diet did not prevent scurvy.	Hess and Unger.[44]
368	Raw.	do.	Thirty-five grams cured scurvy developed in previous experiment.	do.
369	Cooked ¾ hour in 10% vinegar.	do.	Thirty-five grams did not prevent scurvy.	do.
370	Raw.	do.	Ten grams daily per guinea pig did not cure scurvy.	do.
371	do.	Young carrots.	Ten grams daily cured scurvy in guinea pigs.	do.
372	Commercially canned and stored one year.	Strained juice from canned tomatoes.	One and one-half cc. daily per guinea pig did not prevent scurvy. 3.0 cc. did in some cases. 5.0 did in all cases.	do.
373	Boiled 5 minutes.	Same tomato juice as above but boiled before feeding.	Five cc. cured scurvy but growth was not quite as good as for the unboiled.	do.
374	Boiled ¼ hour.	Germinated peas and lentils.	Lost 75 per cent of their antiscorbutic value for guinea pigs.	Chick and Delf.[148]
375	Similar to Expt. 358 but blanched 4 minutes and processed 1½ hours first day, 1 hour second day. Thermometer in center showed a temperature of 212° F. 2 hours 20 minutes. Stored 2 to 3 months.	Canned young crisp runner beans.	The drained beans were fed and had lost 90 per cent of the antiscorbutic value; *i. e.*, they contained only 10 per cent of the initial amount. But they constituted only 63 per cent of the contents of the can.	Campbell and Chick.[146]
376	Untreated.	Raw potato.	Ten grams per day per guinea pig protected from scurvy.	Givens and McCluggage.[149]

Effect of Heat on Vitamin C in Other Vegetables—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
377	Heated ¼ hour at 212° F.	Potato.	Ten grams gave equally as good protection as raw. Do not state if cooking water was fed.	Givens and McCluggage.[149]
378	Heated 1 hour at 212° F.	do.	Ten grams daily did not appreciably delay scurvy. Do not state if cooking water was fed.	do.
379	Raw.	Swede juice.	Two and one-half cc. daily per guinea pig protected against scurvy.	Delf.[136]
380	Heated 1 hour at 176° F.	do.	Five cc. daily per guinea pig protected against scurvy.	do.
381	Heated 1 hour at 212° F.	do.	Five cc. daily per guinea pig protected against scurvy.	do.
382	Heated 1 hour at 230° F.	do.	Five cc. daily per guinea pig protected against scurvy.	do.
383	Heated 1 hour at 266° F.	do.	Ten cc. daily per guinea pig protected against scurvy.	do.
384	Boiled 1 hour.	Canned tomato juice.	Fifty per cent of antiscorbutic property was lost.	LaMer, Campbell and Sherman.[150]
385	Boiled 4 hours.	do.	Seventy per cent of antiscorbutic property was lost.	do.
386	Heated at 259° F., in open jars in autoclave, and heated at 259° F., in hermetically sealed bottles.	Oats and fresh hay.	Guinea pigs on this diet died of scurvy in a little more than 20 days when it was heated in open jars but thrived for more than 2 months, to end of experiment when it was heated in sealed jars.	Rossi.[151]
387	Untreated.	Fresh tomatoes.	Two and one-half grams daily protected guinea pig from scurvy.	Givens and McCluggage.[152]
388	Heated 1 hour at 212° F.	do.	Ten grams daily protected guinea pig against scurvy.	do.
389	Canned and processed ½ hour at 250° F.	Experimentally canned tomatoes.	Ten grams daily protected guinea pig against scurvy.	do.

Effect of Heat on Vitamin C in Other Vegetables—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
390	Commercially canned.	Canned tomatoes afterthree years' storage.	Three cc. daily protected guinea pig against scurvy.	Givens and McCluggage.[152]
391	Heated ¼ hour at 212° F.	Same canned tomatoes after boiling.	Ten grams daily protected guinea pig against scurvy.	do.
392	Dried, then heated ¼ hour at 212° F.	Dried tomatoes.	Two grams (dry substance) daily protected guinea pig against scurvy.	do.
393	Sterilized at 257° to 266° F. Time not given.	Mixed vegetables.	Young rabbits died: 500 gram rabbits in 15 days; 700 gram rabbits in 30 days; 850 gram rabbits in 2 months; 1000 gram rabbits thrived.	Lopez, Lomba and Porter.[20]
394	Commercially canned.	Corn, beans and peas.	Contain considerable antiscorbutic vitamin.	Schield.[250]
395	Raw, home-cooked 15 minutes at 212 commercially canned, blanching 1 to 5 minutes and processing 70 to 120 minutes.	Spinach.	Approximate minimum amounts as antiscorbutic for guinea pigs was less than 1 gm. raw more than 10 gm. home-cooked and less than 4 gm. canned. Excessive blanching apparently decreased Vitamin C but extending process from 70 minutes to 120 minutes did not.	Eddy, Kohman and Carlsson.[211]

The Effect of Drying on Vitamin C in Fruits.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
396	Room temperature until dry.	Orange juice.	The alcoholic extract of 4 grams daily cured and prevented scurvy in guinea pigs.	Hess and Unger.[186]
397	Unknown.	Dried prunes.	Of no antiscorbutic value.	do.
398	Evaporated nearly to dryness. Free citric acid removed.	Orange juice.	Unharmed as antiscorbutic for guinea pigs.	Hess and Unger.[21]

Effect of Drying on Vitamin C in Fruits—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
399	Dried by Merrell-Soule process. Stored 3½ months.	Orange juice powder.	Equivalent of 3 cc. fresh juice daily per guinea pig cured and prevented scurvy.	Givens and McCluggage.[153]
400	Heated 50 hours at 131° to 140° F. Dried to ⅓ its volume, then mixed with soy bean flour and dried completely.	Orange juice powder in soy bean flour.	Equivalent of 6¼ cc. fresh juice daily per guinea pig did not protect from scurvy; 12½ cc. cured and protected.	do.
401	Heated 5 days at 55° to 59° F., dried over sulfuric acid in vacuo, mixed with lactose and gum tragacanth; stored 3 months.	Lemon juice.	Antiscorbutic value undiminished.	Bassett-Smith.[137]
402	Heated 4 hours at 122° to 126° F. until dry. 2 years storage at room temperature.	Orange juice powder.	Practically all antiscorbutic retained.	Harden and Robinson.[154]
403	Fourteen months' storage at 84° F. after the two year's storage at room temperature.	Same orange juice powder as above.	Reduced the antiscorbutic value ½.	do.
404	Dried by Merrell-Soule process and stored 14 months to 2 years.	Orange juice powder; grape juice powder; tomato juice powder; raspberry juice powder; grapefruit juice powder; lemon juice powder. (Raw and neutralized).	All these substances except grape juice powder and raspberry juice powder contained a significant amount of the antiscorbutic vitamin. Definite figures not given.	Givens and Macy[155]

Effect of Drying on Vitamin C in Fruits—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
405	Dried by spraying into heated chamber at 131° to 158° F.	Orange juice powder.	Guinea pigs receiving the equivalent of 1¼ cc. raw juice daily never developed scurvy.	McClendon, Bowers, Sedgwick and Dick.[156]
406	Heated at 131° to 140° F. or at 95° to 104° F. until dry.	Apples and bananas, also peeling from these.	Ten grams daily weighed fresh per guinea pig no longer protected against scurvy whereas the fresh did. Same amount of peeling gave complete protection.	Givens, McCluggage and Van Horn.[138]
407	Commercially dried.	Peaches, apples, apricots, pears, prunes, cherries, loganberries.	When fed in not too excessive amouuts, only peaches were able to maintain life of guinea Pig. Four grams peaches daily per pig delayed scurvy three or four months but did not prevent it.	Echman.[188]
408	Dessication by suitable means.	Orange.	Vitamin C may be conserved.	Osborne & Mendel.[251]
409	Dried.	Thompson seedless, loose muscat or seeded muscat raisins.	Contain no Vitamin C.	Dutcher & Outhouse.[218]

The Effect of Drying on Vitamin C in Milk.

410	Heated 1 minute at 241° F. to dry. Roller process.	Milk powder.	Equivalent of 80 cc. fresh milk daily per guinea pig cured scurvy.	Hess and Unger.[21]
411	Dried by Just Hatmaker process. Heated few seconds at 241° F.	do.	Equivalent of 80 cc. fresh milk daily per guinea pig cured scurvy. Also effective in curing scurvy in infants.	Hess and Unger.[44]
412	Merrell-Soule process.	do.	Twenty-five or 50 per cent of guinea pigs ration with oats did not prevent scurvy.	Hart, Steenbock and Smith.[142]

Effect of Drying on Vitamin C in Milk—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
413	Powdered by Hatmaker process. Stored 1 to 12 months.	Milk Powder.	Could not cure guinea pigs of scurvy with it, but 250–300 grams daily per monkey cured scurvy. Of the raw milk, 100–150 cc. per 300-400 gram guinea pig or 2 to 3 kilogram monkey sufficed to prevent scurvy.	Barnes and Hume.[46]
414	Heated few seconds at 230° F. Just roller process.	Milk powder from dry winter feed.	Equivalent of 80 cc. fresh milk daily per guinea pig had scarcely any antiscorbutic value.	Hess, Unger and Supplee.[48]
415	Heated few seconds at 230° F. Just roller process.	Milk powder from pasture feed.	Had marked antiscorbutic value.	do.
416	Merrell-Soule process.	Milk powder.	Had very little antiscorbutic value.	Hart, Steenbock and Ellis.[157]
417	California Central Creameries process.	Milk powder-	Had very little antiscorbutic value.	do.
418	Just roller process.	do.	Retained most of its antiscorbutic property.	do.
419	Dried, roller process.	Winter milk powder, Swedes in cows ration.	Equal to raw milk and to summer milk in antiscorbutic value.	Jephcott and Bacharach.[158]
420	Dried, roller process.	Summer milk powder.	Equal to raw milk in antiscorbutic value but no better than winter milk if swedes were fed.	do.
421	Dried, spray process.	Summer milk powder from same milk as above.	Most of its antiscorbutic value was lost.	do.
422	Powdered by spray process under conditions known to be favorable to Vitamin C preservation.	Milk.	As rich in Vitamin C as equivalent amount of the liquid milk taken daily from the same vat.	Cavanaugh, Dutcher and Hall.[252]

The Effect of Drying on Vitamin C in Vegetables.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
423	Heated at 99° F. until dry and stored 6 months in closed bottles.	Cabbage.	Fourteen guinea pigs receiving 30 grams daily all died in 21 to 37 days.	Holst and Frölich.[160]
424	Heated at 86° F. in vacuo until dry and stored 6 months in closed bottles.	do.	Fourteen guinea pigs receiving 30 grams daily all died in 21 to 37 days.	do.
425	Heated at 104° to 126° F. until dry.	do.	One gram dry substance daily per guinea pig considerably delayed scurvy.	Givens and Cohen.[161]
426	Heated at 167° to 176° F. 2 hours. Dried 2 days at 149° to 158° F.	do.	Antiscorbutic value for guinea pigs was destroyed.	do.
427	Cooked ½ hour. Dried 2 days at 149° to 158° F.	do.	Antiscorbutic value for guinea pigs was destroyed.	do.
428	Cooked, then dried 2 days at 149° to 158° F.	Potatoes.	The equivalent of 5 grams raw potatoes daily per guinea pig did not delay scurvy.	do.
429	Commercially dried.	Mixed vegetables.	Five grams daily per guinea pig on hay-oats diet neither prevented nor cured scurvy.	Hess and Unger.[135]
430	Dried at 122° to 131°F. Stored a few weeks.	Carrots.	Five grams had no antiscorbutic value for guinea pigs.	do.
431	Dried at room temperature Stored 7 months.	do.	Five grams had no antiscorbutic value for guinea pigs.	do.
432	Heated at 160°F. until dry.	Young freshly plucked carrots.	Four and one-half grams daily per guinea pig cured scurvy.	Hess and Unger.[44]
433	Unknown.	Commercially dried carrots.	Four and one-half grams did not cure scurvy in guinea pigs.	do.
434	Heated 35 to 52 hours at 95° to 104° F. until dry.	Tomatoes.	Ten grams undried daily per guinea pig cured and prevented scurvy as against one gram dried tomatoes.	Givens and McCluggage.[163]

Effect of Drying on Vitamin C in Vegetables—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
435	Heated 13 to 26 hours at 131° to 140° F. until dry.	Tomatoes.	One gram daily per guinea pig cured and prevented scurvy.	Givens and McCluggage.[163]
436	Dried 2 days over radiator at 138° to 156° F.	Cabbage.	Three grams per day prevented scurvy in guinea pig on oats diet.	Cohen and Mendel.[97]
437	Dried by heating 6 to 8 hours at 95° to 104° F.; 4 to 6 hours at 131° to 140° F.; or 2 to 3 hours at 167° to 176° F.	Potatoes, sliced.	Much of the antiscorbutic property was lost. Most at the higher temperature of drying.	Givens and McCluggage.[149]
438	Baked 45 to 55 minutes at 399° F. then heated at 95° to 113° F. until dry.	Baked potatoes, riced and dried.	Two and one-half grams daily per guinea pig protected against scurvy.	do.
439	Heated at 99° F. 1 week until dry. Stored at room temperature in open vessel at 99° F.	Cabbage, cut thin and dried.	The antiscorbutic property was lost more rapidly when dried at room temperature than at 99° F; three grams fed daily per guinea pig in this and 5 succeeding experiments.	Holst and Frölich.[164]
440	Stored in dry and wet dessicator.	do.	Not much antiscorbutic property was lost in 4 weeks in dry but in wet atmosphere all was lost.	do.
441	Stored over sulfuric acid 15 months.	do.	Antiscorbutic value was retained.	do.
442	Stored over phosphoric pentoxide 18 months, then soaked 12 hours and boiled ½ hour in ½ per cent sodium chloride.	do.	Had very pronounced antiscorbutic value.	do.
443	Stored 18 months without phosphoric pentoxide at 39° to 55° F.	do.	Some antiscorbutic value retained but not as much as when stored with phosphoric pentoxide.	do.

Effect of Drying on Vitamin C in Vegetables—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
444	Stored with calcium chloride.	Cabbage, cut thin and dried.	All antiscorbutic value lost.	Holst and Frölich.[164]
445	Untreated.	Cabbage, raw.	One gram daily protected guinea pig from scurvy.	Ellis, Steenbock and Hart.[165]
446	Heated 35 hours at 149° F. in carbon dioxide until dry.	Cabbage,	Equivalent of 1.5 grams raw cabbage daily did not protect guinea pig.	do.
447	Scalded or steamed few minutes, then sun dried, then boiled 30 minutes and drained.	Tomatoes, potatoes, cabbages.	Retained to a considerable extent the Vitamin C. Five grams, equivalent to 50 grams raw, daily per guinea pig, prevented scurvy.	Shorten and Roy.[116]
448	do.	Carrots, brinjal, spinach, turnips, turnip tops.	Practically of no antiscorbutic value.	do.
449	Dried at room temperature and stored 2 to 3 weeks.	Cabbage.	There is a loss of over 93 per cent of antiscorbutic vitamin.	Delf and Shelton.[79]

Effect of Oxidation on Vitamin C.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
450	Heated ½ hour at 145° F. Pasteurized experimentally.	Milk.	Of 6 infants fed upon it, none developed scurvy. One child was cured of scurvy by changing to this milk.	Hess.[162]
451	Pasteurized as above, then held 24 hours on ice.	Same milk as above.	Out of eight infants fed upon it, two developed scurvy.	do.
452	Unheated, held on ice 48 hours.	Same milk as above.	Of four infants receiving it, one developed scurvy. The fresh milk prevented scurvy.	do.
453	Stored in refrigerator.	Orange juice.	Three cc. daily cured scurvy in guinea pig but growth was not as good as with raw juice.	Hess and Unger.[185]

Effect of Oxidation on Vitamin C—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
454	Neutralized and shaken ½ hour.	Tomato juice.	Some antiscorbutic property was lost.	Hess.[37]
455	Shaken ½ hour.	Milk.	Some antiscorbutic property was destroyed.	do.
456	Homogenizing.	do.	Caused scurvy outbreaks in France and Switzerland.	do.
457	Oxygen bubbled through while heating in water bath.	Tomato juice of p H 4.3 and 8.3.	Complete destruction of antiscorbutic vitamin as against 50 per cent destruction with p H 4.3 and 62 per cent with p H 8.3.	LaMer.[62]
458	Aerated 2 hours at room temperature.	Orange juice.	One cc. daily per guinea pig still effective as before in protecting against scurvy.	Ellis, Steenbock and Hart.[165]
459	Treated 3 hours with ½ volume of hydrogen peroxide.	do.	One cc. daily gave no protection.	do.
460	Treated with enough potassium permanganate to give pink color and allowed to react one hour.	do.	One cc. gave no protection.	do.
461	Hydrogen bubbled through.	do.	One cc. as effective as untreated juice.	do.
462	Ten per cent its volume of 3½ per cent hydrogen peroxide added.	do.	Three cc. gave slightly less satisfastory growth in guinea pig than untreated juice.	Dutcher Harsha and Hall.
463	Treated as above, then heated ½ hour at 145° F.	do.	Three cc. gave very little protection against scurvy.	do.
464	Treated with hydrogen peroxide as above and boiled 30 minutes.	do.	Three cc. gave no protection against scurvy.	do.
465	Four cc. hydrogen peroxide added to one quart milk and stored over night in incubator.	Milk.	Eighty cc. was of no more antiscorbutic value for guinea pig than milk heated 1 hour at 248° F.	Hess an Unger.[166]

Effect of Oxidation on Vitamin C—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
466	Organic acids removed.	Lemon juice.	Guinea pig was protected against scurvy by 1.5 to 2.0 cc. daily.	Zilva.[167]
467	Air passed through 12 hours.	do.	Three to 5 cc. daily delayed scurvy only very slightly.	do.
468	Heated 1 hour at 212° F. while air was passed through.	do.	Scurvy was not appreciably delayed by 1.5, 3 or 6 cc. daily.	do.
469	Heated 2 hours at 212° F. while carbon dioxide was passed through.	do.	Feeding 1.5, 4 and 6 cc. daily to guinea pigs showed it had lost no antiscorbutic.	do.
470	Ozone or air bubbled through at ordinary temperatures.	Decitrated lemon juice.	Destroyed Vitamin C.	Zilva.[203]
471	Boiling in atmosphere of carbon dioxide 2 hours.	do.	Did not appreciably effect Vitamin C.	do.
472	Boiled 1 hour in air.	do.	Completely destroyed Vitamin C.	do.
473	Decitrated concentrated and stored in absence of oxygen.	do.	No loss of Vitamin C in three months.	do.

Effect of Alkali on Vitamin C.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
474	Rendered alkaline with sodium hydroxide.	Orange juice.	When made twentieth normal alkaline and stored 24 hours, 3, 5 or 7 cc. per day per guinea pig did not delay scurvy. When made fiftieth alkaline on day of feeding 3, 5 or 7 cc. only slightly delayed scurvy. Reacidifying just previous to feeding did not better it.	Harden and Zilva.[168]
475	Neutralized with sodium carbonate heated 1 hour at 212° F.	do.	Very little effect on antiscorbutic value.	Delf.[136]

Effect of Alkali on Vitamin C—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
476	Eleven ounces sodium bicarbonate added to 38 gallons summer milk. Acidity lowered from 26.5 to 19.9. Dried by roller process.	Summer milk powder.	Had slightly less antiscorbutic value than when not neutralized.	Jephcott and Bacharach.[158]
477	Rendered 0.05 normal alkaline to phenolphthalein.	Canned tomato juice.	The antiscorbutic vitamin was not destroyed if fed shortly after making alkaline, 5 cc. fed daily per guinea pig.	Hess and Unger.[44]
478	do.	Orange juice.	Scurvy was cured by feeding 5 cc. freshly alkalinized juice daily per guinea pig. When stored in refrigerator 24 hours before feeding the pigs again succumbed to scurvy.	do.
479	Heated 1 hour at 212° F. after adding alkali to change pH from 4.2 to 5.1. Reacidified after heating. Stored at 50° F. 5 days while being fed.	Canned tomato juice.	Tomato juice to which no alkali was added lost 50 per cent of Vitamin C. With acids partly neutralized, 58 per cent was lost. The pH dropped to 4.9 during heating.	LaMer, Campbell and Sherman.[169]
480	Same as above, but enough alkali was added to raise pH to 11.	do.	The pH dropped to 9 while being heated. The loss of Vitamin C was 61 to 65 per cent.	do.
481	Same as previous experiment, but not reacidified.	do.	Loss of Vitamin C was 90 to 95 per cent.	do.
482	Cooked by throwing into excess 0.5 per cent boiling ammonium carbonate solution for 20 minutes.	Germinated cow peas.	Produced the same degree of softening as 1 to 1½ hour boiling in water and there was less destruction of Vitamin C. Cooked for same time there was less destruction in water.	Delf.[183]

Effect of Alkali on Vitamin C—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
483	Exposed to air ½ hour.	Alkaline decitrated lemon juice.	Lost 80 per cent of its Vitamin C and the pH was raised.	Zilva.[203]
484	Air excluded 24 hours.	do.	Lost none of its Vitamin C with no change in pH.	do.

Vitamin C, Miscellaneous.

485	Soaked 24 hours; weight doubled.	Peas and lentils.	Thirty to 40 grams daily per guinea pig prevented scurvy. Ten grams did not delay scurvy. Unsoaked, they were 1/15 as effective as raw cabbage.	Chick and Delf.[148]
486	Germinated 48 hours after soaking 24 hours. Weight doubled.	do.	Ten grams daily protected guinea pig from scurvy.	do.
487	Fermentation.	Sauer Kraut 4 weeks old.	Equivalent of 2.5 to 5.0 grams cabbage daily did not protect guinea pig from scurvy, whereas 1.0 gram raw cabbage did.	Ellis, Steenbock and Hart.[165]
488	Fermentation.	Best ensilage from green corn.	Twenty grams daily per guinea pig gave no evidence of having any antiscorbutic value.	do.
489	Untreated.	Potato.	Equal to cabbage or dandelion as antiscorbutic for guinea pigs.	Bezssonoff.[170]
490	Pressed in hydraulic press.	Potato marc.	Amounts equal to original potato had little effect as antiscorbutic.	do.
491	Pressed in hydraulic press.	Potato juice.	Less effective than equivalent of intact potato.	do.
492	Pressed in hydraulic press.	Marc and juice.	Juice only slightly reinforced marc, indicating a destructive effect due to the process.	do.

Vitamin C, Miscellaneous—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
493	Pasteurized ½ hour at 145 °F. in glass vessel.	Milk.	Guinea pigs receiving 80 cc. daily did not develop scurvy.	Hess.[144]
494	Pasteurized as above but in copper vessel.	Same milk.	Guinea pigs receiving 80 cc. daily developed scurvy. Milk contained 3 to 4 parts copper per million. With 2 cc. of orange juice guinea pigs thrived on it.	do.
495	Raw.	Old carrots such as are given laboratory animals.	Guinea pigs receiving 35 grams daily developed scurvy. Young carrots prevented it.	Hess.[2]
496	Exposed to ultra-violet rays for 8 hours at pH 2.34 and after neutralizing.	Lemon juice.	The antiscorbutic value was undiminished.	Zilva.[69]
497	Heated 1 hour at 212° F. while being exposed to 4 adjacent 500-watt lamps.	Canned tomato juice.	No greater destruction than when heated in dark.	LaMer, Campbell and Sherman.[169]
498	Preserved in 0.06 to 0.09 per cent sulfite for 18 to 22 months at lower than room temperatures.	Lemon juice.	Lost 2/5 to 4/5 of its antiscorbutic value.	Davey.[177]
499	In cold storage at 37° to 42° F.	Oranges.	If they remained sound they apparently retained their antiscorbutic value, but the great majority spoiled in this experiment.	do.
500	Boiled in 0.005 and in 0.5 per cent citric acid.	Sprouted peas and lentils.	The destruction of vitamin C was hastened rather than retarded.	Chick and Delf.[148]
501	Hydrogen bubbled through while in boiling water bath.	Tomato juice with pH 4.3 and 8.3.	Life of guinea pigs receiving 2, 3 and 4 cc. daily was from 31 to 50 or more days as against 90 days when heated in absence of air and hydrogen.	LaMer.[62]

Vitamin C, Miscellaneous—Cont'd.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
502	Heated and then supplemented with fat soluble vitamins.	Grain rations.	Did not produce good growth or reproduction in rats, though their livers were as rich in Vitamin C as ever.	Lepkovsky and Nelson.[200]
503	Hydrochloric acid.	Decitrated lemon juice.	Partially destroyed Vitamin C.	Zilva.[203]
504	Ultraviolet rays.	do.	Had no effect.	do.
505	Pasteurization after adding 2.5, 6.0 and 9.0 p.p.m. copper.	Milk.	Antiscorbutic vitamin appreciably reduced by 2.5 p.p.m. copper. but apparently not more by 6.0 or 9.0 p.p.m.	Hess and Weinstock.[245]
506	Freed from sugar by fermentation and concentrated.	Decitrated lemon juice.	Vitamin C is stable in absence of oxygen and may be stored for long time.	Zilva.[254]

TABLE 4.—THE STABILITY OF VITAMIN E.

The Effect of Heat on Vitamin E.

EXPERIMENT NUMBER	TREATMENT	SUBSTANCE	RESULTS	AUTHORS
507	Cooked.	Foods containing VitaminX	No evidence of loss of this factor.	Evans and Bishop.[255]
508	Autoclaved 1½ hours under 15 to 18 lbs. pressure.	Georgia Velvet beans.	Vitamin E is not destroyed.	Sure.[256]
509	Boiled 1 hour.	Beef muscle.	No loss of Vitamin E.	Evans and Bishop.[257]
510	Autoclaved 1 hour under 15 lbs. pressure.	Lettuce.	do.	do.

The Effect of Saponification on Vitamin E.

511	Saponified at 86° F. with 20 per cent KOH in alcohol.	Wheat germ oil.	Vitamin E went with little or no destruction in unsaponifiable residue.	Evans and Burr.[258]

LITERATURE

1. Delf, Biochem. J., 1918, 12, 416.
2. Hess, Harvey Lectures, 1920-21. J. Am. Med. Assoc., 1921, 76, 693.
3. James Lind, A Treatise on Scurvy, 2nd Edition, London, 1757.
4. Eijkman, Virchow's Arch., 1897, 148, 523; 149, 187.
5. Smith, U. S. Dept. Agr. Ann. Rep., Bur. Animal Ind., 1895-6, p. 172.
6. Holst and Frölich, J. Hyg., 1907, 7, 619, 634 and 661.
7. Dutcher, Harshaw and Hall, J. Biol. Chem., 1921, 47, 483; Science 1921, May 6, 446.
8. Dalyell, Brit. Med. J., 1920, July 31.
9. Sherman and Pappenheimer, Proc. Soc. Exp. Biol. Med., 1921, 18, 193; J. Exp. Med., 1921, 34, 189.
10. McCollum, Simmons, Shipley and Park, J. Biol. Chem., 1921, 47, 507.

10a. McCollum, Simmons, Shipley and Park, J. Biol. Chem., 1922, 50, 5.

10b. Powers, Parks, Shipley, McCollum and Simmons, J. Am. Med. Assoc., 1922, 78, 159.

11. Hess and Unger, Pros. Soc. Exp. Biol. Med., 1920-21, 18, 298; J. Am. Med. Assoc., 1921, 77, 39.
    Hess, and Gutman, J. Am. Med. Assoc., 1922, 78, 29.
12. Hess, Unger and Pappenheimer, J. Biol. Chem., 1922, 50, 77.
13. McDonald and McCollum, J. Biol. Chem., 1921, 45, 307.
14. Fulmer, Nelson and Sherwood, J. Am. Chem. Soc., 1921, 43, 186 and 191.
    Nelson, Fulmer and Cessna, J. Biol. Chem. 1921, 46, 77.
15. Andrews, Philip, J. Sci., 1912, Series B, 7, 67.
16. Funk, Die Vitamine, 1914.
17. Chick and Hume, Lancet, London, 1918, 1, 1.
18. Parsons, J. Biol. Chem., 1920, 47, 587.
19. Budd, 1840.
20. Medical and Surgical History of the War of the Rebellion, Washington, 1888, 1, pt. 3, 683.
21. Hess and Unger, Am. J. Dis. Child., 1919, 17, 221.
22. Wilcox, Brit. Med. J., 1920, Jan. 17, 73.
23. Chick and Hume, Trans. Soc. Trop. Med. Hyg., 1917, 10, 141, 156, 179.
24. Neuman, Deutsch. Med. Wochensch, 1902, 647.
25. Heubner, Berl., Clin. Wochensch., 1903, 285.
26. Hess, Am. J. Dis. Child., 1916, 12, 152.
27. Hess, Brit. Med. J., 1920, 2, 154.
28. Hess, N. Y. State J. Med., 1920, 20, 209.
29. Lopez, Lamba & Porter, Compt. rend., 1921, 172, 1682.
30. Voegtlin, J. Am. Med. Assoc., 1914, 63, 1094.
31. Goldberger, J. Am. Med. Assoc., 1916, 66, 471; 1918, 71, 944.
32. Wilson, J. Hyg., 1921, 20, 1.
33. Roussel, Traité de la pellagre, Paris, 1866.
34. Stepp, Biochem. Z., Berlin, 1909, 22, 452.
35. Hopkins, J. Physiol., 1912, 44, 425.
36. Gibson and Conception, Philip J. Sc., 1916, Series B, 11, 119.
37. Cooper, J. Hyg., 1912, 12, 436; 1914, 14, 12.
38. Osborne and Mendel, J. Biol. Chem., 1918, 34, 537; 1920, 41, 515.
39. Daniels, Byfield and Laughlin, Am. J. Dis. Child., 1919, 18, 546.
40. Hopkins, Biochem. J., 1920, 14, 721.
41. McCollum, Simmons and Pitz, J. Biol. Chem., 1916, 27, 33.
42. Drummond, Coward and Watson, Biochem. J., 1921, 15, 540.
43. Chick, Hume and Skelton, Biochem. J., 1918, 12, 131. **Also ref. 17.**
44. Hess and Unger, J. Biol. Chem., 1919, 38, 293.

45. Barnes and Hume, Lancet, 1919, **2**, 323. Biochem. J., 1919, **13**, 306.
46. Dutcher, Pierson and Biester, Science, 1919, 1, 184; C. A., 1920, **14**, 3700.
47. Hart, Steenbock and Ellis, J. Biol. Chem., 1920, **42**, 383.
48. Hess, Unger and Supplee, J. Biol. Chem., 1920, **45**, 229.
49. Dutcher, Eckles, Dahl and Schaefer, J. Biol. Chem., 1920, **45**, 119.
50. Dutcher, Pierson & Biester, J. Biol. Chem., 1920, **42**, 301.
51. Hughes, Fitch and Cave, J. Biol. Chem., 1921, **46**, Sc. Proc. 50.
52. Kennedy and Dutcher, J. Biol. Chem., 1922, **50**, 339.
53. McClendon and Henry, Science, 1921. Nov. 11, 469.
54. Brit. Med. Res. Comm., 1919, No. 38, 65.
55. Drummond and Coward, Lancet, 1921, Oct. 1, 698.
56. Mitchell, J. Biol. Chem., 1919, **40**, 399.
57. Emmett and Luros, J. Biol. Chem., 1920, **41**, Proc. 7; **43**, 265.
58. Funk and Dublin, J. Biol. Chem., 1921, **48**, 437.
59. Daniels and McClurg, J. Biol. Chem., 1919, **37**, 201.
60. Chick and Hume, Trans. Soc. Trop. Med. & Hyg., 1917, **10**, 141. J. Roy. Army Med. Corps, 1917, **29**, 121.
61. Chick and Hume, J. Biol. Chem., 1919, **39**, 203.
62. LaMer, J. Ind. Eng. Chem., 1921, 13, 1108.
63. Osborne and Mendel, J. Biol. Chem., 1915, **20**, 379.
64. Osborne and Mendel, J. Biol. Chem., 1916, **24**, 37.
65. Steenbock, Boutwell and Kent, J. Biol. Chem., 1918, **35**, 517.
66. Drummond, J. Physiol., 1918-19, **52**, 95.
67. Drummond, J. Physiol., 1919, **52**, 346.
68. Drummond, Biochem. J., 1919, **13**. 81.
69. Zilva, Biochem. J., 1919, **13**, 164; 1920, **14**, 740.
70. Drummond and Coward, Biochem. J., 1920, **14**, 734.
71. Hopkins, Brit. Med. J., 1920, **2**, 147, Biochem. J., 1920, **14**, 725.
72. Steenbock, Sell and Buell, J. Biol. Chem., 1921, **47**, 89.
73. McCullum and Davis, Pros. Soc. Exp. Biol. Med., 1914, **11**, 101.
74. Osborne and Mendel, J. Biol. Chem., 1917, **32**, 369.
75. Daniels and Nichols, J. Biol. Chem., 1917, **32**, 91.
76. Steenbock and Boutwell, J. Biol. Chem., 1920, **41**, 163.
77. Hume, Biochem. J., 1921, **15**, 30.
78. McCollum, The Newer Knowledge of Nutrition, New York, 1918, p. 156.
79. Delf and Skelton, Biochem. J., 1918, **12**, 448.
80. Steenbock and Gross, J. Biol. Chem., 1919, **40**, 501.
81. Steenbock and Gross, J. Biol. Chem., 1920, **41**, 149.
82. McCollum, Reported by Rosenau in the Boston Medical and Surgical Journal, 1921, May 5.
83. Osborne and Mendel, J., Biol. Chem., 1920, **41**, 549.
84. Hart, Steenbock and Hoppert, J. Biol. Chem., 1921, **48**, 33.
85. McCollum and Davis, J. Biol. Chem., 1914, **19**, 245.
86. Steenbock and Boutwell, J. Biol. Chem., 1920, **42**, 131.
87. Chick and Hume, Proc. Roy. Soc. London, 1917-18, B. **90**, 60.
88. Drummond, Biochem. J., 1917, **11**, 255.
89. Hawk, Fishback and Berguin, Am. J. Physiol., 1919, **48**, 211.
90. Williams, J. Biol. Chem., 1919, **38**, 465.
91. Eijkman, Arch. Hyg., 1906, **58**, 150.
92. Grijns, Cited by Emmet and Luros, Ref. 57.
93. Holst, J. Hyg., 1907, **7**, 619.
94. McCollum and Davis, J. Biol. Chem., 1915, **23**, 247.
95. Weill and Mouriquand, Compt. rend. Soc. Biol., 1915, **78**, 649.
96. McCollum, Simmons and Pitz, J. Biol. Chem., 1917, **29**, 521.
97. Cohen and Mendel, J. Biol. Chem., 1918, **35**, 425.
98. Chick and Hume, Roy. Soc. London, 1919, B. **90**, 44.
99. Emmet and Stockholm, J. Biol. Chem., 1920, **43**, 287.

100. Davis, J. Home Econ., 1920, **12**, 209.
101. Miller, J. Biol Chem, 1920, **44**, 159.
102. Schaumann, Arch. Schiff. u. Tropen. Hyg., 1910, Suppl. **14**, **64**.
103. Cooper, J. Hyg., 1912, **12**, 448.
104. Voegtlin and Lake, Am. J. Physiol., 1918-19, **47**, 558. J. Pharmacol. Exp. Therap., 1918, **11**, 167.
105. Vedder, J. Hyg., 1918, **17**, 1.
106. Osborne and Mendel, Carnegie Inst. of Washington, 1911, Pub. 156, pts. 1 and 2.
107. Osborne and Mendel, J. Biol. Chem., 1919, **37**, 187.
108. Daniels and Stuessy, Am. J. Dis. Child., 1916, **11**, 45.
109. Daniels and Laughlin, J. Biol. Chem., 1920, **44**, 381.
110. Rosenau, The Boston Medical and Surgical Journal, 1921, May 5.
111. Denton and Kohman, J. Biol. Chem., 1918, **36**, 249.
112. Osborne and Mendel, J. Biol. Chem., 1920, **41**, 451.
113. Whipple, J. Biol. Chem., 1920, **44**, 175.
114. Cooper, Biochem. J., 1914, **8**, 250.
115. Osborne and Mendel, J. Biol. Chem., 1918, **34**, 17.
116. Shorten and Roy, Biochem. J., 1921, **15**, 274.
117. Johnson and Hooper, U. S. Pub. Health Repts., 1921, **36**, **2037**.
118. Siedell, Vitamine Symposium, New York, 1921, Sept. 6.
119. Shiga and Kusama, Arch. F. Schiffs—u. Tropenhyg., Beih. 3, May, 1911. Funk, The Vitamins, Translation of Second Edition by Dubin, 1922.
120. Vedder and Williams, Philippine J. Sci., 1913, B, **8**, 175.
121. Williams and Seidell, J. Biol. Chem., 1916, **26**, 431.
122. Sullivan and Voegtlin, J. Biol. Chem., 1916, **24**, Sc. Proc. 16.
123. Voegtlin, Sullivan and Myers, U. S. Public Health Rept., 1916, **31**, 935.
124. Steenbock, J. Biol. Chem., 1917, **29**, Sc. Proc. 27.
125. Cooper and Funk, Lancet, 1911, **2**, 1266.
126. McCollum and Simmons, J. Biol. Chem., 1918, **33**, 55.
127. Souza and McCollum, J. Biol. Chem., 1920, **44**, 113.
128. Byfield, Daniels and Laughlin, Am. J. Dis. Child., 1920, **19**, 349.
129. Osborne and Leavenworth, J. Biol. Chem., 1921, **45**, 423.
130. Funk, The Vitamines, 2nd edition, Translation by Dubin, 1922, p. 243.
131. Davis, J. Inf. Dis., 1917, **21**, 392.
132. Lloyd, J. Path. Bact., 1916-17, **21**, 113.
133. Agulhan and Legroux, Compt. rend., 1918, **167**, 597.
134. Bottomley, Proc. Roy. Soc. London, 1915-17, B, **88**, 237; **89**, **102**, **481**.
135. Hess and Unger, Proc. Soc. Exp. Biol. Med., 1917-18, **15**, **82** and **141**. J. Biol. Chem., 1918, **35**, 479 and 487.
136. Delf, Biochem. J., 1920, **14**, 211.
137. Bassett-Smith, Lancet, 1920, **1**, 1102; **2**, 997.
138. Givens, McCluggage and Van Horn, Proc. Soc. Exp. Biol. Med., 1921, **18**, 140; Am. J. Dis. Child., 1922, **23**, 210.
139. Pierson and Dutcher, Science, 1920, **51**, 70; C. A. 1920, **14**, **3700**.
140. Frölich, Z. Hyg. Infektions-Krankh., 1912, **72**, 155.
141. Hess, Am. J. Dis. Child, 1914, **8**, 385.
142. Hart, Steenbock and Smith, J. Biol. Chem., 1919, **38**, 305.
143. Taylor, Cited by Rosenau, Boston Med. Surg. J., 1921, May 5.
144. Hess, J. Ind. Eng. Chem., 1921, **13**, 1115.
Hess and Unger, Proc. Soc. Exp. Biol. Med., 1921, **19**, 119.
145. Hume, Biochem. J., 1921, **15**, 163.
146. Campbell and Chick, Lancet, 1919, **2**, 320.
147. Chick and Rhodes, Lancet, 1918, **2**, 774.
148. Chick and Delf, Biochem. J., 1919, **13**, 199.
149. Givens and McCluggage, J. Biol. Chem., 1920, **42**, 491.
150. LaMer, Campbell and Sherman, Proc. Soc. Exp. Biol. Med., **1921**, **18**, 122.

151. Rossi, Arch. fisiol., 1918, **16**, 125; Physiol. Abst., 1919, **4**, 335; C. A., 1919, **14**, 1844.
152. Givens and McCluggage, Proc. Soc. Exp. Biol. Med., 1921, **18**, 164.
153. Givens and McCluggage, Am. J. Dis. Child., 1919, **18**, 30.
154. Harden and Robinson, Biochem. J., 1920, **14**, 171; 1921, **15**, 521.
155. Givens and Macy, J. Biol. Chem. Sc. Proc., 1921, **46**, 11.
156. McClendon, Bowers, Sedgwick and Dick, J. Biol. Chem. Sc. Proc., 1921, **46**, 9 and 10.
157. Hart, Steenbock and Ellis, J. Biol. Chem., 1921, **46**, 309.
158. Jephcott and Bacharach, Biochem. J., 1921, **15**, 129.
159. Holst and Frölich, Z. Hyg., 1912, **72**, 1.
160. Holst and Frölich, Z. Hyg., 1913, **75**, 334.
161. Givens and Cohen, J. Biol. Chem., 1918, **36**, 127; Proc. Soc. Exp. Biol. Med., 1917-18, **15**, 126.
162. Hess, Am. J. Dis. Child., 1917, **14**, 337.
163. Givens and McCluggage, J. Biol. Chem., 1919, **37**, 253.
164. Holst and Frölich, J. Trop. Med. Hyg., 1920, **23**, 261.
165. Ellis, Steenbock and Hart, J. Biol. Chem., 1921, **46**, 367.
166. Hess and Unger, Proc. Soc. Exp. Biol. Med., 1921, **18**, 143.
167. Zilva, Lancet, 1921, **1**, 478.
168. Harden and Zilva, Lancet, 1918, **2**, 320.
169. LaMer, Campbell and Sherman, J. Am. Chem. Soc., 1922, **44**, 172; Proc. Soc. Exp. Biol. Med., 1921, **18**, 122.
170. Bezssonoff, Compt. rend., 1921, **172**, 92; Bull. soc. hyg., 1921, **8**, 622; C. A. 1921, **15**, 1746.
171. Osborne, Wakeman and Ferry, J. Biol. Chem., 1919, **39**, 35.
172. Hogan, J. Biol. Chem., 1917, **30**, 115.
173. Eddy, Heft and Stevenson, J. Biol. Chem., 1922, **51**, 83.
174. McCarrison, Studies in Deficiency Diseases, Oxford Medical Publications, 1921.
175. Wheeler, J. Am. Med. Assoc., 1922, **78**, 955.
176. Sherman and Smith, The Vitamins, 1922.
177. Davey, Biochem. J., 1921, **15**, 83.
178. Coward and Drummond, Biochem. J., 1921, **15**, 530.
179. Wilson, J. Biol. Chem., 1922, **51**, 455.
180. Fürst, Z. hyg., 1912, **72**, 121.
181. Grijns, Genees. Tijds. Med. Ind., 1901, **41**, 3.
182. Wiltshire, Lancet, 1918, **2**, 811.
183. Delf, Lancet, 1922, **1**, 576.
184. Hess, Scurvy—Past and Present, 1920.
185. Harden and Zilva, Biochem. J., 1918, **12**, 408.
186. Drummond, Biochem. J., 1919, **13**, 77.
187. Chick and Hume, Biochem. J., 1920, **14**, 135.
188. Eckman, J. Am. Med. Assoc., 1922, **78**, 635.
189. Sherman, Macleod and Kramer, Proc. Soc. Exp. Biol. Med., 1920, **18**, 41.
190. Goldberger and Tanner, Pub. Health Reports, 1922, **37**, 462.
191. Goldberger, Waring and Willets, 1914, **29**, 2821.
192. Coward and Drummond, Biochem. J., 1921, **15**, 530.
Jameson, Drummond and Coward, Biochem. J., 1922, **16**, 482.
Drummond and Zilva, Biochem. J., 1922, **16**, 518.
193. Coward, Biochem J., 1923, **17**, 135.
194. Kohman, Eddy and Carlesson, Ind. Eng. Chem., 1924, **16**, 1261.
Eddy, Kohman and Carlsson Ind. Eng. Chem., Jan., 1925.
195. Steenbock and Black, J. Biol. Chem., 1924, **61**, 405.
196. Goldblatt and Soames, Biochem. J., 1923, **17**, 446; 622.
197. Kugelmass and McQuarrie, Science, 1924, **60**, 272.
198. Luce, Chemistry and Industry, 1924, **43**, 313.

199. Santos, Proc. Soc. Exp. Biol. Med., 1922, **19**, 2; Amer. J. Physiol., 1922, **59**, 310.
200. Lepkovsky and Nelson, J. Biol. Chem., 1924, **59**, 91.
201. Jones and Associates,
    Navy beans, J. Biol. Chem., 1920, **41**, 379.
    Lima beans, Am. J. Physiol., 1921, **56**, 205.
    Adsuki bean, Am. J. Physiol., 1921, **56**, 208.
    Georgia Velvet bean, J. Biol. Chem., 1921, **47**, 285.
    Georgia and Chinese Velvet bean, Am. J. Physiol., 1921, **57**, 61.
    Also J. Biol. Chem., 1921, **46**, 9; 1922, **52**, 209.
    Cow pea and Field pea, J. Biol. Chem., 1922, **52**, 209.
    Lentil, J. Biol. Chem., 1924, **59**, 243.
202. McCollum, Simmonds, Becker and Shipley, J. Biol. Chem., 1922, **53**, 293.
203. Zilva Biochem. J., 1922, **16**, 42.
204. Goldblatt and Zilva, Lancet, 1923, Vol. 2, 647.
205. Steenbock and Nelson, J. Biol. Chem., 1923, **56**, 355.
206. Delf, Biochem. J., 1924, **18**, 93.
207. Drummond, Cited in British Med. J., 1922, Vol. 1, 112.
208. Morgan and Stephenson, Amer. J. Physiol., 1923, **65**, 491.
209. Morgan and Chaney, Am. J. Physiol., 1924, **68**, 397.
210. Hess and Weinstock, Proc., Soc. Exp. Biol. Med., 1924, **21**, 441.
211. Eddy, Kohman and Carlsson, Ind. Eng. Chem., 1925, **17**, 69.
212. Miller, J. Home Econ., 1924, **16**, 18.
213. Stanley and Stillman, J. Home Econ., 1924, **16**, 558.
214. Hart, Steenbock, Hopper and Humphrey, J. Biol. Chem., 1922, **53**, 21.
215. Hart, Steenbock, Hopper, Bethke and Humphrey, J. Biol. Chem., 1922, **54**, 75.
216. Gaessler and McCandlish, J. Biol. Chem., 1923, **56**, 663.
217. Osborn and Mendel, Proc. Soc. Exp. Biol. Med., 1922, **19**, 187.
218. Dutcher and Outhouse, Proc. Soc. Exp. Biol. Med., 1923, **20**, 450.
219. Steenbock and Sell, J. Biol. Chem., 1922, **51**, 63.
220. McClendon, Proc. Soc. Exp. Biol. Med., 1923, **21**, 276.
221. Morgan and Francis, Amer. J. Physiol., 1924, **69**, 67.
222. Vedder, Milit. Surg., 1921, **49**, 502. Physiol. Abst. **7**, 364; through Chem. Abst., 1923, **17**, 1987.
223. Zucker, Pappenheimer and Barnett, Proc. Soc. Exp. Biol. Med., 1921–22, **19**, 167.
    Steenbock, Jones and Hart, J. Biol. Chem. 55, XXVI; 58, 383.
224. Wright, J. Soc. Chem. Ind., 1923, **42**, 509, through Chem. Abst., 1924, **18**, 1346.
225. Drummond, Zilva and Coward, J. Soc. Chem. Ind., 1924, **43** 236, through Chem. Abst., 1924, **18**, 3206.
226. Holmes, Ind. Eng. Chem., 1924, **16**, 295.
227. Holmes, Ind. Eng. Chem., 1924, **16**, 964.
228. Bleile and Seymour, Amer. J. Physiol., 1923, **63**, 421, through Chem. Abst., 1923, **7**, 3360.
229. Dubin and Funk, Proc. Soc. Exp. Biol. Med., 1923, **21**, 139.
230. Karr, J. Biol. Chem., 1920, **44**, 255.
231. Nitzescu, Compt. Rend. Soc. Biol., 1923, **89**, 1244, through Chem. Abst., 1924, **18**, 1690.
232. Sherman and Spohn, J. Am. Chem. Soc., 1923, **45**, 2719.
233. Sherman and Edgeworth, J. Am. Chem. Soc. 1923, **45**, 2712.
234. Daniels and Stearns, J. Biol. Chem., 1924, **61**, 225.
235. Sherman and Grose, J. Am. Chem. Soc., 1923, **45**, 2728.
236. Johnston, U. S. Public Health Repts., 1921, **36**, 2044, through Chem. Abst., 1922, **16**, 3936.
237. Morgan, Amer. J. Physiol., 1924, **69**, 634.
238. Findley, Biochem. J., 1923, **17**, 887.

239. Jansen, quoted by Findley, Biochem. J., 1923, **17**, 887.
240. Wright, J. Soc. Chem. Ind., 1923, **42**, 403, through Chem. Abst., 1924, **18**, 130.
241. Smith, Bergheim and Hawk, Proc. Soc. Exp. Biol. Med., 1921, **19**, 228.
242. Santos, Am. J. Physiol., 1922, **59**, 310.
243. Delf, Biochem. J., 1924, **18**, 674.
244. Hess and Unger, Proc. Exp. Biol. Med., 1922, **19**, 119.
245. Hess and Weinstock, J. Am. Med., Assn., 1924, **82**, 952.
246. Lesne and Vagiliano, Compt. Rend. Soc. Biol., 1924, **90**, 393, through Chem. Abst., 1924, **18**, 1851.
247. Anderson, Dutcher, Eckles and Wilbur, Science, 1921, **53**, 446.
248. Eddy, Shelow, Pease, Tichter and Walkins, J. Home Econ., 1923, **15**, 15; Proc. Soc. Exp. Biol. Med., 1922, **19**, 155.
249. Eddy and Kohman, Ind. Eng. Chem., 1924, **16**, 52.
250. Schield, Proc. Soc. Exp. Biol. Med., 1924, **21**, 341.
251. Osborne and Mendel, Proc. Soc. Exp. Biol. Med., 1922, **19**, 187.
252. Cavanaugh, Dutcher and Hall, Am. J. Dis. Child, 1923, **25**, 498; Ind. Eng. Chem., 1924, **16**, 1070.
253. Eddy, Kerr and Williams, J. Amer. Chem. Soc., 1924, **46**, 2846.
254. Zilva, Biochem. J., 1924., **18**, 182.
255. Evans and Bishop, J. Metabol Research, 1923, **3**, 233.
256. Sure, J. Biol. Chem., 1924, **58**, 693.
257. Evans and Bishop, Anatomical Record, April, 1924, 203.
258. Evans and Burr, Anatomical Record, April, 1924, 203.
259. Hartwell, Biochem. J., 1925, **19**, 226.
260. Dutcher, Francis and Combs, J. Dairy Sci., 1926, **9**, 379.
261. LaMer, Dissertation, 1921, Columbia University.
262. Delf, Biochem. J., 1925, **19**, 141.
263. Eddy, Kohman, Carlsson and Halliday, Ind. Eng. Chem., 1926, **18**, 302.
264. Miller, J. Home Econ., 1924, 16, 18 and 74; 1925, 17, 377.
265. Eddy, Kohman and Carlsson, Ind. Eng. Chem. 1926, **18**, 85.
266. Coward, J. Biol. Chem., 1927, **72**, 765.
267. Hughes, Fitch, Cave and Riddeil, J. Biol. Chem., 1927, 309.
268. Goldberger, U. S. Public Health Reports, 1926, **41**, 297.
269. Kohman, Eddy and Halliday, Ind. Eng. Chem., 1928, **20**, 202.
270. Eddy, Kohman and Halliday, Ind. Eng. Chem., 1929, **21**, 347.
271. Craven and Kramer, Jour. Agr. Research, 1927, **34**, 385.
272. Kramer, Eddy, Kohman and Zall, Ind. Eng. Chem. (Early issue).
273. McCollum, "The Health Bulletin," June 1928, North Carolina State Board of Health, Raleigh, N. C.

PUBLICATIONS
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BULLETINS

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*7-L. Processing of String Beans and Beets. 1923. (Superseded by Circular 13-L).
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12-L. Processing of Corn and Pumpkin. 1924. (Superseding Circular 8-L).
13-L. Processing of String Beans and Beets. 1925. (Superseding Circular. 7-L).
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